JOHNS HOPKINS UNIVERSITY CIRCULARS

Published with the approbation of the Board of Trustees

VOL. X.—No. 88.] BALTIMORE, MAY, 1891. [PRICE, 10 CENTS.

MORPHOLOGICAL NOTES.

FROM THE BIOLOGICAL LABORATORY OF THE JOHNS HOPKINS UNIVERSITY.

EDITED BY WILLIAM K. BROOKS, PH. D., PROFESSOR OF ANIMAL MORPHOLOGY AND DIRECTOR OF THE CHESAPEAKE ZOÖLOGICAL LABORATORY.

On the Structure and Development of the Gonophores of a certain Siphonophore belonging to the Order Auronectae (Haeckel). By W. K. BROOKS and E. G. CONKLIN.

Among the specimens brought by the U. S. Fish Commission Steamer Albatross (1887–88) from the Pacific and left with us to be studied, was a single specimen of a Siphonophore, which is probably identical with the genus Rodalia, described by Haeckel in his "Challenger" Report. The interest in this form is the greater since Haeckel regards it as so unlike all other Siphonophores as to necessitate its being placed in an entirely new order, which he calls the Auronectae, or Siphonophores with an Aurophore. But a few specimens, and those badly broken, have ever been obtained, and this fact has led Claus,[1] among others,[2] to doubt whether Haeckel was justified in describing these few fragmentary specimens as the type of a new order. The specimen here described was taken off the Galapagos Islands, in latitude 0° 46′ south, longitude 89° 42′ west, and like all the previously described specimens of this group, is badly mutilated, though in an excellent histological condition.

The present paper has to do merely with the structure and development of the gonophores of the specimen mentioned, an account of the remaining organs being reserved for a future communication.

Haeckel says of the gynophores, or female gonophores:[3] "The female gonophores are much more varied in shape and composition than the androphores. They are easily distinguished from them by their more rounded (usually pear-shaped) form and their longer stalks. There occur the following remarkable variations:

"*A. Monovone Gynophores.* Each female medusome develops only a single large ovum."

(1.) "The gynophore develops a single very large ovum surrounded by a double envelope; the inner envelope is the thin manubrial wall containing a smaller or larger blind spadicine cavity, sometimes a network of irregular spadicine canals; the outer envelope is the umbrella of the medusoid person, with four narrow radial canals and a small distal ring canal connecting the latter; this is probably the normal and most frequent form of the ripe gynophore."

(2.) "The same form but with four blind radial canals (reduced in the distal half)."

(3.) "The same form (as 1 and 2) but with eight equidistant, regular, radial canals." Fig. 12, Pl. II.

(4.) "The same form (as 1 to 3) but with a variable number (five to ten) of irregular, branched and anastomosing spadicine canals."

(5.) "The same form (as 1 to 4) but without radial canals in the reduced umbrella."

"*B. Polyovone Gynophores.* Each female medusome develops an ovarium, composed of a variable number of ovules placed in the wall of the modified manubrium. The umbrella seems to be usually reduced, very thin walled without radial canals; often it has disappeared."

(1.) "The gynophore is a medusome with rudimentary umbrella; the spadicine canal (or the original gastric cavity of the medusa) is central, straight, and runs in the axis of the manubrium (Pl. II, Figs. 9 and 10); the ovules are regularly disposed around it."

(2.). "The gynophore is a medusome with rudimentary umbrella; the spadicine canal is eccentric, curved and runs on one side of the manubrium; it embraces the ovarium as a crescent-shaped or semicircular blind canal."

(3.) "The gynophore is a simple sporosac, the manubrium without umbrella; the ovules are arranged equally around the central spadicine canal."

(4.) "The gynophore is a compound sporosac, without umbrella; two or three (rarely more, sometimes only one) buds developing from off the outside of the primary manubrium (Pl. II, Fig. 11). The buds or the secondary sporosacs, contain either a single large ovum or a group of several small ovules; they have usually a long pedicel, and its canal arises from the base of the primary spadix. The different remarkable modifications of gonophores here enumerated exhibited in the adult spirit specimens examined, showed no regular distribution, but occurred in very variable number and association. A further accurate research on living and well preserved specimens is required to make out their mutual relations and significance."

Although a careful search was made for them, the androphores or male gonophores mentioned by Haeckel were not observed. It seems impossible that they could have been overlooked, since they were carefully looked for both in sections and in surface views of a large number of gonodendra; and while female gonophores were found in every stage of development and in great abundance, not a trace of an androphore could be found. The writers therefore conclude that the specimens examined bear female gonophores only. Professor Haeckel's description of the androphores occupies but twelve lines, and he gives but three figures of them, all surface views and very unsatisfactory. It would therefore seem possible, at least, that Professor Haeckel mistook for male gonophores some long, spindle-shaped gynophores filled with yolk, but into which the egg nucleus had not yet passed, or from which it had been forced out by pressure (several such gonophores were seen). It seems proper here to mention the fact that an examination of the sexual organs of forty or fifty specimens of Physalia has shown that they were all males. The structures described by Haeckel as the female gonophores of Physalia are not gonophores, but swimbells, as is shown by an examination of living expanded specimens.

---

[1] C. Claus, "On the Organism of the Siphonophora," etc. Ann. and Mag. Nat. Hist., Vol. 4, and Arb. Zool. Inst., Wein, Bd. 8.

[2] J. Walter Fewkes, "On Angelopsis," etc. Ann. and Mag. Nat. Hist., Vol. 4.

[3] "Challenger" Report on Siphonophora, p. 295.

Concerning the female gonophores we are able to speak with certainty. Since the present investigation has shown that the so-called "Polyovone Gynophores" show no trace of medusoid structure, and are therefore strictly speaking not gonophores at all, but merely pouches containing ova, the term "polyovone gynophore" has been replaced throughout this paper by the term "egg-pouch." The so-called "Monovone Gynophores" are true gonophores, and are known throughout this paper merely as female gonophores. The remarkable varieties of "Monovone" and "Polyovone Gynophores," mentioned by Haeckel, were not observed at all, and it seems probable that at least many of these varieties were merely different stages in the development of the female gonophores.

The structure of the mature gonophore is so complicated that it will best be understood if the development of the gonophore be traced from its simple beginnings to its final complex form. The earliest stage shown is in Fig. 6, in which a small bud, *A*, is represented as arising from the distal end of a large egg pouch, *B*, which also bears a well developed gonophore containing an egg. The egg pouch itself communicates with the digestive cavity of the stem or gonostyle, *S*. The ectoderm has disappeared over most of the external surface of the bud. The latter is merely a protuberance blind at its distal end, opening into the egg-pouch at its proximal end and lined with endoderm, which is continuous with that which lines the egg-pouch and the digestive cavity.

The next stage is shown in Fig. 1. As before, the gonophore arises from an egg-pouch; however, in this case there are no clearly marked ova in the latter, though it and the stem of the gonophore are filled with yolk, *Y*. The egg-pouch is connected with the stem of the gonodendron near the point where the pedicel, *P*, of the gonophore arises, but at a slightly lower level than that represented in the figure. The invagination at the end of the bud is caused by the pushing in of a solid mass of ectoderm, *B N*; this is the bell nucleus ("glockenkern"), and the cavity of the invagination, filled with the mass of ectoderm, represents the umbrella cavity.

Fig. 2 shows a stage still more advanced. The egg pouch is connected to the stem at a different level from that shown in the figure. The egg cells in the pouch are quite numerous and in all stages of development. It is clearly seen from the sections that the egg cells are endoderm cells which have grown in size, protruding from the simple layer of endoderm which originally lined the egg pouch into the cavity of the latter. In many cases the egg cells in growing have torn the endoderm cells from the supporting lamella and have carried them up along their sides, so that the endoderm cells come to lie between the large egg spheres. Usually the egg cells are found in their original position in the endoderm layer, *i. e.* on the supporting lamella; some, however, have separated from the lamella and are free in the cavity of the egg pouch or in that of the pedicel, *P*, of the gonophore. In the specimen figured two egg cells lie in the cavity of the pedicel below the invaginated endoderm, while one has crowded into the narrow space between the two layers of cathammal endoderm, *K. En.*, on the side of the bell cavity. The ectoderm in the bell cavity, which in the previous stage was a solid mass, now lines the cavity down to the bottom of the invagination, where it turns up on each side and unites with the ectodermal mass which fills the mouth of the invagination. The endoderm and supporting lamella also bend outward at the bottom of the invagination. This feature varies greatly in different individuals; in some it is scarcely seen at all, in others it is quite marked. There can be little doubt that the structure represents the manubrium or proboscis of the ancestral medusa.

The next stage in the development of the gonophore, and the one most interesting, namely, that of the migration of the egg from the egg pouch into its final position, was the stage most difficult to obtain. On careful search, however, several such stages were found. Fig. 3 shows an egg from the egg pouch just breaking through the endoderm and supporting lamella. The mass of yolk still fills the pedicel while the distal part of the egg, *Y*, has pushed into its final resting place, carrying the ectoderm of the manubrium before it and flattening it out against the ectoderm of the subumbrella. There is a wide break, *R*, in the endoderm and supporting lamella through which the nucleus of the egg is just entering. Gradually, however, as the egg gets into its permanent position this break closes and we reach the condition shown in Fig. 5. The egg is now in its permanent position and the endoderm and lamella are closing in behind it, *T*, to shut it off from the pedicel and egg pouch. A second smaller egg is shown just at the break, which, if one may judge from other similar cases, will be broken down and absorbed by the larger egg now in position.

Fig. 4, a stage corresponding to Fig. 3, is nevertheless different from it, in that the gonophore does not arise out of the egg pouch but from the stem of the gonodendron. However, from the same opening in the stem a small egg pouch, *B*, arises. In this case it is impossible to say whether the egg originated in the small egg pouch and then migrated into its present position in the gonophore, or whether it originated above or below its present level and then migrated through the stem to its present position. We have in no case been able to find an egg originating in the stem or in any other place than the egg pouch, and we consider it extremely improbable that they do arise in any other position. Nor have we been able to find any egg migrating through the stem, so that in the case of Fig. 4 it is probable that the egg did originate in the adjacent egg pouch and then migrated into its present position. The condition of the egg pouch in this case indicates that it is undergoing degeneration, and considering the fact that the egg pouch is present in all cases where the gonophore is young, and that as this becomes more and more developed the egg pouch becomes smaller or is absent altogether, we hold it probable that the eggs not only originate in the egg pouch and afterward migrate into the gonophore, where alone they mature, but that the egg pouch also furnishes nutriment to the egg in the gonophore, and that as the latter grows larger the former is absorbed by it.

In Fig. 6 the gonophore is still further developed. The edges of the ruptured endoderm and lamella which, in the previous figure, had closely approached and had almost shut off the egg from the egg pouch and the digestive cavity, have now grown together, completely closing the break by which the egg entered. The egg does not completely fill the gonophore, a small cavity, *U*, being left at its distal end, which is the remnant of the umbrella cavity. At this point the two layers of the ectoderm immediately surrounding the egg are separated; the inner layer (nearest the egg), *M. Ec.*, is the ectoderm of the manubrium, the outer layer, *S. Ec.*, is the ectoderm of the subumbrella; outside this are two layers of endoderm, the cathammal lamellae, closely pressed together, and in which no remnant of radiating canals may be found, but which do show traces of a ring canal at the distal end of the gonophore where the endoderm folds on itself. Covering the outside of the gonophore and filling the mouth of the bell is a layer of ectoderm which is continuous with that covering the stem. In fact, all the ectoderm of the gonophore is in one continuous layer, as appears in the figures. This layer was at first invaginated (primary bell invagination), and then subsequently evaginated by the pushing in of the egg. In the same way the endoderm is in one continuous layer. The endoderm of the stem, gonostyle and egg pouch being continued through the pedicel of the gonophore, and along its side to its distal end, and there folded back on itself by the primary invagination. The endoderm just below the egg and separating it from the pedicel shows a slight upward protuberance, *M. En.*, on each side. This represents the manubrial endoderm, and is the beginning of a fold of endoderm which pushes up on all sides of the egg and nearly surrounds it, leaving only a small place where the egg still remains in contact with the ectoderm. Fig. 7, *M. En.*, shows these endoderm folds more largely developed than in Fig. 6; there is a slight cavity (continuous with the digestive cavity) running up between the folds.

Fig. 8 is a gonophore almost mature, though many reach a size two or three times as great as this. The endoderm folds have grown up far around the egg, and the cavity which they enclosed in the former stage is no longer seen. At their distal ends the folds are imperfectly cleft into a number of finger-like processes which arise from the proximal part of the folds as the fingers do from the hand, only in this case, to carry out the simile, the fingers are connected by a web; the egg is surrounded by these as a ball which is held in the hand is surrounded by the palm and fingers. In the figure the folds are constricted in several places, which is due to the fact that several of these finger-like processes are cut across in the section. These endoderm folds and finger-like processes have a marked glandular appearance; and there can be no doubt that the cells of these endoderm

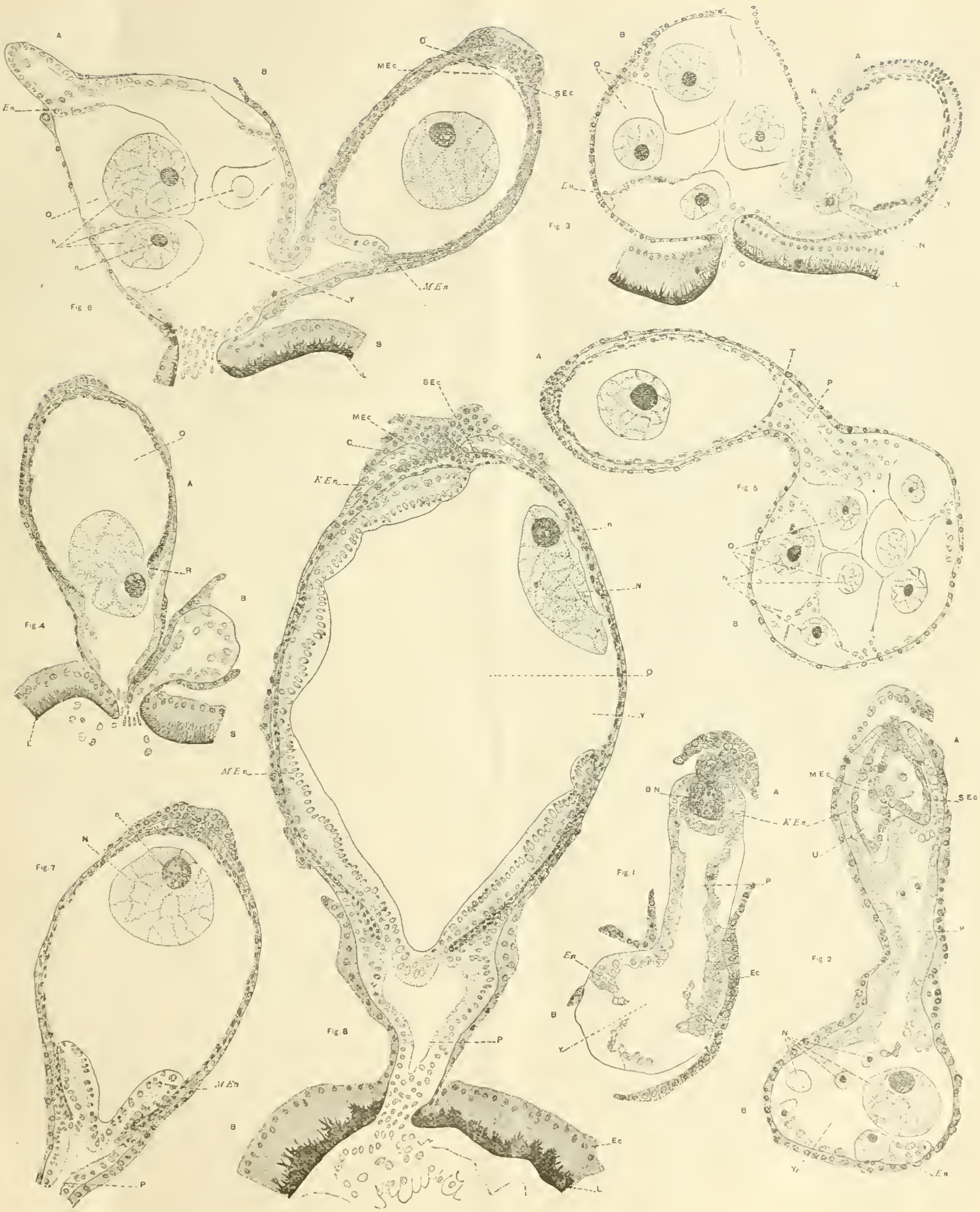


Fig. 6
A
B
En
O
N
n
MEc
SEc
MEn
Y
S
L
Fig. 3
B
A
O
R
En
Y
N
O
L
Fig. 5
A
T
P
O
N
B
Fig. 4
O
A
R
B
L
S
Fig. 8
SEc
MEc
C
KEn
n
N
O
Y
MEn
P
B
Ec
L
Fig. 7
n
N
MEn
P
Fig. 1
BN
A
KEn
P
En
Ec
B
Y
Fig. 2
A
MEc
SEc
U
P
N
B
Yl
En

Conklin, del.

Digitized by the Internet Archive
in 2008 with funding from
Microsoft Corporation

http://www.archive.org/details/no88circular10johnuoft

folds secrete yolk which is passed into the egg. No egg pouch is present, it having probably been absorbed. The nucleus occupies the position which it has in all the mature eggs, viz., immediately beneath the ectoderm.

The development of the egg pouches was not observed minutely, though it is evident that they arise as mere diverticula of the stem; they have but a single layer of ectoderm and of endoderm, which is continuous with that of the stem. Haeckel represents the eggs of the egg pouch ("Polyovone Gynophore") as constituting a single layer next the supporting lamella, the eggs being everywhere covered by a continuous layer of endoderm, and separated from each other by endoderm cells. This work has shown that the eggs are not covered with a layer of endoderm, but that they form a part of the endoderm layer; and if the eggs are separated from each other by cells, they are endoderm cells which have been torn from the lamella by the growth of the egg.

In Fig. 2, several stages in the development of some of the endoderm cells into egg cells can be seen. It may be that the germ cells migrate along the stem, as Weismann has observed in many cases, and finally take a position in the layer of endoderm lining the egg pouches, but nothing was observed to indicate that this does take place, and to all appearance the cells which are destined to become egg cells are not different from the other endoderm cells. So far as observed no eggs come to maturity in the egg pouches; they are either passed on into the gonophore or are broken down to nourish the egg which does pass into the gonophore. Usually but one gonophore arises from an egg pouch, though in a few cases two or even more arise from the same pouch.

To sum up: The egg pouch must be regarded as a part of the stem where the growth of the egg cells may take place while the gonophore is developing. As soon as the gonophore is formed one of the eggs, already quite large, passes into it, where it lies between the ectoderm and endoderm of the manubrium. Then by the disintegration of the egg cells remaining in the egg pouch, and by the formation of large endoderm folds which have a secretory function, the egg is rapidly nourished and grows to a very large size. The whole contrivance is to secure as rapid a development of the sexual cells as possible, such as has been so excellently shown by Weismann for very many Hydromedusae and Siphonophores.

The fact that only female gonophores have been found on this "Albatross" specimen, and the probability that the specimens examined by Haeckel were females (since, as we have seen, the evidence that male gonophores were present is very slight), suggests that the male may be widely different in form. And it is highly probable that the female of Physalia is so different from the male, which alone has been found, that if ever described, it has probably been classed as a wholly different genus.

Explanation of Figures.

All the figures represent longitudinal sections through the gonophores, and were drawn with the camera lucida, under a magnifying power of about 250 diameters. The space occupied by the yolk, *Y*, of the ovum, *O*, is left unshaded.

Reference Letters.

A.—Gonophore.
B.—Egg Pouch.
B N.—Bell Nucleus.
C—Circular Canal.
Ec.—Ectoderm.
En.—Endoderm.
K En.—Cathammal Endoderm.
L.—Supporting Lamella.
M Ec.—Manubrial Ectoderm.
M. En.—Manubrial Endoderm.
N.—Egg Nucleus.
n.—Nucleolus.
O.—Ova.
P.—Pedicel.
R.—Rupture of Endoderm and Lamella.
S.—Stem or Gonostyle.
S Ec.—Subumbrellar Ectoderm.
T.—Reunion of Ruptured Endoderm and Lamella.
U.—Umbrella Cavity.
Y.—Yolk.

Preliminary Note on the Embryology of Crepidula fornicata and of Urosalpinx cinerea.

By E. G. Conklin.

Crepidula fornicata.

The time and manner in which Crepidula lays its eggs has been described by Dr. McMurrich.[1]

The cleavage follows the type found in Fusus, Planorbis, Neritina, etc. The first furrow is, with regard to the future embryo, a median longitudinal one, and divides the ovum into exactly equal right and left halves. (The method of determining the relation of the first furrow to the embryo cannot be explained without several figures). The second furrow is at right angles to the first and transverse to the long axis of the embryo, and it divides the egg into four equal macromeres. Of these, two meet in the centre in a line which Rabl[2] has called the "cross furrow;" the other two are acute toward the centre and do not meet each other. By the position of the macromeres with regard to the "cross furrow," the first and second cleavage furrows may easily be distinguished, *e.g.*, if the egg be viewed from the formative pole and so that one of the cleavage furrows is in the line of vision, the macromere to the right of this furrow and farthest from the observer will be acute at its centre if the furrow in the line of vision be the second cleavage furrow; it will be obtuse, *i.e.*, will meet the opposite macromeres in the "cross furrow" if the furrow in the line of vision be the first cleavage furrow. Of course the reverse would hold true if the egg were viewed from the vegetative pole. The examination of many hundreds of eggs has shown that the position of the macromeres in relation to the "cross furrow" and to the first and second cleavage planes is a constant one, and that the first and second furrows may always be distinguished in the way mentioned. The macromeres as distinguished from the micromeres do not again divide until late in the course of segmentation, and as they do not change their relative position it becomes very easy to orient all the future furrows and cells with reference to the first two furrows. The polar bodies which are at the centre of the ectodermal area also mark the centre of the dorsal surface of the embryo, while the blastopore closes and the definitive mouth appears almost directly opposite them. Until after the formation of the blastopore the chief axis is the one drawn from the centre of the ectodermal to the centre of the endodermal area; with regard to this axis the egg is for some time radially symmetrical; the chief axis of the embryo (the antero-posterior) is at right angles to the chief axis of the egg. At an early period there is a trace of a segmentation cavity, which however is soon obliterated. The formation of micromeres proceeds with wonderful regularity, following the law formulated by Rabl,[3] new micromeres always being formed in fours either by being cut off from the four macromeres or by the division of four micromeres already formed. When twenty-four micromeres have been formed one of the macromeres, which later developments show to be on the posterior side of the ovum and to the left of the median line, divides into a larger ventral and a smaller dorsal moiety. The smaller cell, which, unlike the ectoderm cells, contains yolk, moves to the right until it comes to lie at the posterior end of the median furrow between the two posterior macromeres; it very soon divides into a right and a left half, and at a later stage these two cells give rise to two mesoblastic bands which extend forward over the right and left sides of the dorsal surface.

Save for these mesoblasts the radial symmetry at the stage with thirty-six micromeres is perfect. At this stage twelve of the micromeres form a cross with three cells in each arm, the crossing of the arms being exactly at the centre of the ectodermal area. Two of the arms lie in the antero posterior axis, two in the transverse axis; one arm is anterior, one posterior, one right and one left. In the next stage the radial symmetry is no longer perfect, since three arms of the cross lengthen so as to contain four cells each, while the posterior arm does not lengthen until later. However, with this exception, the radial symmetry is preserved until fifty-two micromeres are formed; at this stage the posterior arm lengthens by one cell and the three other arms split longitudinally. At the same time each of the macromeres, except the one mentioned above as giving rise to the mesoblast, divides as did the later into a larger and a smaller moiety. The three smaller cells take positions on the periphery of the egg in the furrows separating the macromeres, one at each end of the transverse furrow and one at the anterior end of the longitudinal furrow.

In normal eggs there is not a trace of an invagination at the ectodermal pole, such as has been described for Neritina and Fulga, though eggs which were developing abnormally often showed such an invagination together with other irregularities, *e. g.*, the spreading apart of the macromeres and the formation of large yolk containing cells at the periphery of the ectodermal area instead of the small protoplasmic ectoderm cells which are usually formed.

The gastrula is formed by typical epibole. On all sides the ectoderm cells grow around toward the ventral side at an equal rate; thus the blastopore is formed in the middle of the ventral side. The mesoblasts are carried around with the ectoderm to the ventral side, where they lie at the posterior edge of the blastopore. The mesoblastic bands are soon separated from the mesoblasts; the latter continue to proliferate mesoderm, which extends forward in the lips of the blastopore.

---

[1] A contribution to the Embryology of the Marine Prosobranchs. Studies from Biol. Lab., J. H. U., Vol. 3.

[2] Carl Rabl, Ueber die Entwicklung der Tellerschnecke. Morph. Jahrbüch, Bd. 5.

[3] *Loc. cit.*

The cross above mentioned resembles very much an arrangement of cells figured by Blochmann[1] for Neritina, the terminal cells in the transverse arms of which are called by him velar cells. In Crepidula it seems that no part of the transverse arms forms the velum. However, the cells of the posterior arm grow very large, the nuclei are vesicular and stain lightly, and the cells become covered by fine cilia, which protrude through a thin cuticula; though at first these ciliated cells lie wholly on the posterior side of the ovum, they move forward in the course of development until they come to lie on the anterior side, and as they increase enormously in size, though they seldom divide, it comes about that they cover the anterior part of the dorsal area, extend around over the anterior end of the embryo and down over its sides. These cells finally form the walls of a large head vesicle.

The velum appears first on the ventral side, just anterior to the mouth, and consists at first of a *single* row of cells. Later it is composed of several rows, some of which are adoral, and at least a single row runs posterior to the mouth. It is not completed dorsally until much later, though soon after the definitive mouth is formed the velum splits on each side of the embryo, and about half way between the ventral and dorsal surfaces, into an anterior and posterior branch; the later continues up over the dorsal surface just posterior to the large ciliated cells; the anterior branch, which is the chief one, turns forward over the sides of the head vesicle, and quite late in development the two arms of the anterior branch meet and fuse on the mid line just in front of the ventral part of the preoral velum. Thus two large velar lobes are formed, one on each side. The posterior branch of the velum appears to be the postoral ciliated band, the anterior branch the preoral; from the corners of the mouth to the middle of the sides of the embryo the two are fused, while ventrally they are separated by the mouth and dorsally by the whole diameter of the head vesicle. A postoral band of cilia has been described as present in the veligers of several gastropods, and among these Crepidula,[2] but I am not aware that any one has hitherto found the two separated dorsally. The velum does not become ciliated until quite late in development, though the embryo swims about in the pouch by means of the cilia of the large ciliated cells which form the head vesicle.

The shell gland appears on the dorsal surface immediately posterior to the second or transverse furrow as a prominence of ectoderm cells. In the place of this prominence an invagination afterward appears; the margin of the invagination extends rapidly and a thin cuticle, the first indication of the shell, is secreted by the invaginated cells. As development proceeds the shell becomes asymmetrical, developing more rapidly on the left side than on the right.

The foot arises as a *single* median protuberance just posterior to the mouth. While it shows no trace of a double origin, it occupies a region along which the blastopore closed, so that really the foot may be considered as having arisen on both sides of the blastopore, though the lips of the latter have fused before the former appears. Running from the mouth backward over the median surface of the foot is a row of large ciliated cells resembling those on the dorsal area.

At the posterior end of the embryo three or four large ciliated anal cells appear, and just ventral to these the distal end of the intestine is pressed against the ectoderm. The proctodeal invagination does not occur until late in development. The intestine is a tube with a distinct lumen, its walls being formed of small cells free from yolk. In the course of development its central end, where it opens into the cavity between the yolk spheres is carried anteriorly and to the right. Throughout its whole length the intestine is pressed closely against the ectoderm.

The supra-oesophageal ganglia appear as proliferation of the ectoderm on each side of and dorsal to the mouth; the eyes are formed in connection with these ganglia as involutions of ectoderm. The ganglia of the two sides are connected by a commissure, and from the centre of the latter a nerve runs forward to the centre of the apical plate, where there is a ciliated depression in the ectoderm, which I believe is a sense organ. A commissure connects the supra-oesophageal ganglion of each side with the otocysts. The latter are formed by involution of the ectoderm of the foot, and the pedal ganglion is formed by delamination from the ectoderm at the sides of the foot.

Urosalpinx cinerea.

The breeding habits of Urosalpinx have been fully described by Professor Brooks.[3] The segmentation is almost identical with that described by Professor Brooks[4] for the oyster, and closely resembles the segmentation of Nassa, as described by Bobretzky.[5] The chief difference between the segmentation in Urosalpinx and Crepidula consists in the fact that while the four macromeres of Crepidula are equal in size, the four macromeres of Urosalpinx are very unequal, one being very much larger than the other three. Two furrows appear simultaneously and seem to divide the ovum into one large sphere and two smaller ones. Really, however, one of the smaller spheres is not completely separated from the larger one, and soon after fuses with it. This smaller sphere is merely a constricted portion of the larger sphere and contains the nucleus. Thus it is seen that of the two furrows mentioned, but one is a true cleavage furrow and it divides the egg into a larger and a smaller moiety. At the next stage the smaller moiety divides into two equal parts, and at the same time two protuberances, each containing a nucleus, are pushed out from the larger moiety. One of these protuberances is cut off to form a macromere equal in size with the two smaller ones; the other protuberance is a part of the larger macromere and again fuses with it. There have thus been formed by two vertical furrows comparable to the first and second cleavage furrows of Crepidula, three smaller and one larger macromere.

The antero-posterior axis of the embryo is no longer coincident with the first cleavage furrow as it is in Crepidula, but in order to preserve bilateral symmetry the axis is shifted to one side, so that it passes through the centre of the larger macromere and through the middle one of the three smaller spheres. This new axis crosses the first furrow at an angle of about 45°, and the "cross furrow" is in this case a true cross furrow, being transverse to the long axis of the embryo.

The micromeres are formed very much as in Crepidula. The ectoderm extends posteriorly over the large sphere much more rapidly than it does anteriorly over the three smaller spheres, and the blastopore closes almost directly opposite the formative pole and at a point where the four macromeres meet in the centre. At this point the definitive mouth afterward appears.

Owing to great difficulty in cutting sections of the Urosalpinx egg its development was not carried farther.

Notes on the Physiology of Caravella Maxima, Haeckel (*Physalia Caravella*, Eschscholtz). By ROBERT PAYNE BIGELOW.[6]

During July and the early part of August of the year 1889, Caravellae, Portuguese Men-of-War, were unusually numerous in Vineyard Sound. As during that time I was at the U. S. Fish Commission Station at Woods Holl, I was able to collect, from time to time, a number of specimens for study; and in the large hatching tanks there, kindly set apart for my use, I could keep these animals alive for a week or more.

BEHAVIOR WHEN UNDISTURBED.

(*a*) *General Movements.*

The first thing one sees on looking at a Caravella is the large bladder-like float, pneumatophore, which lies on the surface of the water, usually with its crest laid over on one side (see note). Hanging from the posterior half of the right margin of the ventral surface of the float—taking the apex to be anterior, and the crest to be dorsal—is a multiple series of thickly set cormidia. The immensely long main tentacles, several yards in length, are attached to the float by simple, unbranched pedicels and hang down vertically from the right side of this series of cormidia.

---

[1] F. Blochmann, Ueber die Entwicklung der *Neritina fluviatilis.* Zeit. wiss. Zool., Bd. 36.

[2] McMurrich. J. H. U. Circulars, No. 44, 1885.

[3] Preliminary observations on the development of the Marine Prosobranchs. Studies from the Biological Laboratory, J. H. U., Vol. 1.

[4] The Embryology of the Oyster. Studies from the Biological Laboratory, J. H. U., Vol. 1.

[5] N. Bobretzky. Studien über die Embryonale Entwicklung der Gasteropoden. Archiv. f. Mik. Anat., Bd. 13.

[6] A preliminary abstract of this paper was published in J. H. U. Circulars, No. 80, 1890.

If the Caravella be placed in a tank with transparent sides, on looking at the animal one is immediately struck with the motions of its appendages. They seem to be in a constant state of activity. The large tentacles are always being retracted and extended; and the cormidia are being raised and lowered by the contractions of their peduncles,[1] sometimes separately, sometimes in a sort of unison. This motion is compounded by the separate raising and lowering of the secondary clusters of the cormidia, due to the contraction of the branches of the peduncles. With all this, the siphons and small tentacles of the feeding cormidia and the palpons—mouthless siphons—of the gonodendra are perpetually squirming, extending, and contracting. Looking more closely, one sees that all of the appendages are not often in activity at once, in fact usually only very few are, but there is always some cormidium being raised and lowered, some siphons and palpons squirming and twisting.

If one watches the Caravella for some time, there will be noticed occasionally uneasy movements in the float, a sort of squirming motion, especially when there is a general contraction of the appendages. Perhaps this will be followed by a general shortening of the float, then the apex will be raised above the water by the contraction of muscles of the left side; following this, the left ventral muscles will contract, thus shifting the centre of gravity, and the float will roll over through an arc of ninety degrees, bringing the crest upright. The float may remain a long time in this position, but more often the centre of gravity is soon shifted to the opposite side by the contraction of the muscles of that side and the crest falls over on the water again. The float cannot lie on its left side owing to the position of its appendages.

There are long intervals usually between the contraction of each tentacle, and no rhythm was observed in these motions. The peduncle would often contract without the contraction of the tentacle proper, but the latter does not seem to contract except when the former does. The wave of contraction can be seen to travel downward from the peduncle. The relaxation seems also to start from the same point.

The motion among the cormidia consists chiefly of contractions of the pedicels. There is also some motion in the individual polypoids and secondary tentacles. The motion of the small tentacles is like that of the large ones, viz., a contraction which starts at the base and goes downward, resulting in a progressive partial or complete coiling of the tentacle. The movement of the siphons and palpons is, as already implied, a squirming motion, accompanied sometimes in the former by a peristaltic contraction going from the mouth.

(*b*) *Rhythm.*

At first sight there appears to be no regularity in the movements of the cormidia. Sometimes they will contract separately, at other times together in a rough unison. But if one observes them for some time with the aid of a time-piece, the movements will be seen to be rhythmical. Below is the result of a continuous series of observations made on a single gonodendron in a specimen that had been kept in one of the tanks for two days in good condition. The figures are the numbers of contractions observed during intervals of fifteen seconds, the whole time represented being thirty-five minutes: 0 0 0 2 3 2 2 2 0 0 0 3 2 3 0 0 0 1 3 1 0 1 2 2 1 0 0 1 0 0 0 0 0 3 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2 1 0 0 0 0 0 0 0 0 1 3 3 0 0 0 0 0 3 3 1 0 0 0 0 0 0 0 1 3 2 2 2 2 1 0 0 0 0 0 0 2 2 2 2 0 0 0 0 0 0 0 0 0 3 3 1 3 2 1 0 0 0 0 0 0. It will be seen that the number of contractions in each interval is pretty constant, and that the periods of rest are fairly regular in length. The rhythm would probably have appeared more marked if I had had some instrument beating seconds by which I could have counted the number of seconds between the contractions.

Effects of Unfavorable Conditions.

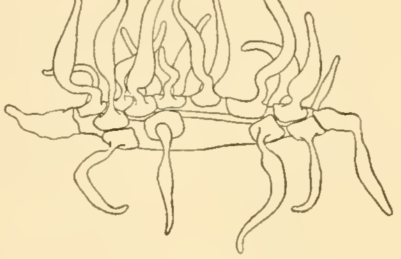
When the animals were brought in from the launch there was always found in the bottom of the jar a number of detached gonodendra, siphons, and pieces of tentacles. These detached parts retained their normal powers of movement; to a slight degree in the tentacles, more strongly in the gonodendra, and to a marked degree in the siphons. The gonodendra were always broken off whole, while the siphons usually came off separately. It was found that any violent agitation would cause this loss of members, and exposure to unfavorable conditions without any violence would produce a similar effect. After the animals had been kept in the tanks several days undisturbed, the siphons, gonodendra, and occasionally a part of a tentacle would begin dropping off. These behaved just as those did that were shaken off by violence. The detachment of a siphon seems always to occur at the same point.

Although my specimens of Caravella were kept in what seemed a large quantity of running sea water and were fed, I did not succeed in keeping them alive over ten days; possibly the feeding was not carefully enough attended to. My first specimens were obtained July 23. On the 29th opaque areas appeared on the floats of all but two of them. In these areas the muscles appeared to be in a state of *rigor mortis*, or at least in a very severe spasm. In those specimens in which these areas were especially well marked the gas in the floats was in a state of unusually high tension. July 30th, four specimens were found with their floats collapsed. In one this state of affairs was evidently brought about by the bursting of the pneumatocyst, for the peduncles were distended by the gas. August 1st, two more specimens were found collapsed and with nearly all of their appendages detached and lying on the bottom of the tank; but as on the day before, the members that remained attached to the float were active. The water in the tank seemed to contain a great deal of the poison peculiar to these animals. After I had cleaned out the tank my arm felt as if it had been stung, although I had not touched one of the tentacles. Of the two remaining specimens, one was found collapsed on the following day; the other one, the smallest one taken July 23d, had its float in almost perfect condition but had lost nearly all of its appendages. The larger specimen was tried and was found still capable of taking food in the usual way. This day two fresh specimens were put into the tank, and on the following day I left Woods Holl for a short journey. Returning August 9th, I found the water in the tanks foul from the decay of detached appendages and the animals dead or nearly so, with the surface of their floats dry and parchment like.

At the apex of the float the position of the stigma is well marked. According to Haeckel, it is capable of being opened or closed at the will of the animal. L. Agassiz says he has never seen it opened and my observations seem to show that this cannot be done voluntarily.

Method of Capturing Prey.

Several times specimens were brought in whose siphons were filled with food. One specimen had several partially digested pieces of small fish attached. The least digested of these fish was a silversides—*Menidia notata* (?)—nearly whole. It was 8.5 cm. long and was held by over fifteen siphons. The soft parts of the integument, head, fins, and tail were completely digested. The mouths of the siphons that were attached to any projecting part, as the head, tail, or a fin, would completely envelope that part. The mouths that were attached to a flat surface were spread out widely so that their edges touched each other. Probably the whole surface of the fish was covered by these mouths, but I could not be certain of this, because as soon as the siphons became detached from their cormidia they began to contract.



Fish with siphons attached as it felt from the caravella. × ½.

---

[1] It may be convenient to borrow from botany the term peduncle for the main stem of the cormidium, and pedicel for its ultimate branches.

Small fish, then, seem to be one of the natural foods of these animals. In order to see how they are captured I put two minnows 6 to 7 cm. long, into a glass jar with a Caravella. The two fish darting about, the smaller one soon struck its side against one of the main tentacles with such force as to wind the tentacle about his middle. He gave one spasmodic jerk, then doubled up paralyzed and, the tentacle contracting, he was drawn up among the cormidia. Soon after this the larger minnow ran his head against a couple of large tentacles, feeling the sting he darted on, only to have the tentacles become fastened all along his side. After a brief but violent struggle the minnow suddenly became motionless and was instantly drawn up to the siphons. These, when their mouths touched either minnow, became quickly fastened to him. After recovering from the shock of the capture both of the fish made considerable resistance, but in each interval between their struggles more siphons would be attached and the fish more firmly held. Gradually their struggles became more and more feeble and in about an hour the fish died. The Caravella was then returned to the tank.

Parts of the fish were found next morning at the bottom of the tank in a very much macerated condition. A freshly killed fish which had been put into another tank at the same time was still quite fresh looking, showing that in the first instance it was a process of digestion, not one of decay.

While the conflict between the fish and the Caravella was being watched, several of the siphons were seen to attach themselves to the sides of the glass jar. This occured on several other occasions, but seemed most marked when the animal was taking food.

This experiment of feeding the Caravella was repeated a number of times. A minnow about 6 cm. long was put into a jar with a specimen that had been in the tank for six days. The minnow swam about rather quietly. It soon, however, struck a tentacle with its head, but only so that about one centimeter of the tentacle was attached to it. Although the attachment was so slight, the fish was unable to shake it off. At the same time, the single tentacle was unable to pull in the fish so long as it resisted. At length, the fish becoming fatigued, its struggles became intermittent. While the minnow struggled the tentacle was unable to pull it in, when its efforts ceased the tentacle likewise relaxed. The fish seemed in a fair way to escape being eaten, when in one of its paroxysms of activity it ran against another tentacle and was immediately drawn up so that a few of the siphons could become attached. As the tentacles gradually let go their hold, these siphons held the fish, and, contracting from time to time, they brought it into contact with the mouths of other siphons, one or more of which would become attached with each contraction until the animal was covered by their expanded mouths. A shrimp was also put into the jar but failed to be caught, although it several times came in contact with the tentacles.

I tried touching a tentacle with my finger and in imitation of the minnow drawing the finger through the water away from the Caravella. The tentacle would remain fastened to the finger but its pull was not preceptible. On allowing, however, the finger immediately to return towards the animal the tentacle would contract. In this experiment the tentacle became so firmly attached that it had to be scraped off with a knife. As long as the tentacle only touched the palmar surface of the hand there was no unpleasant sensation, but if it touched the arm or the back of the hand the sensation was very painful, quite like the sting of a bee (see note).

EFFECTS OF STIMULATION.

(*a*) *Food as a Stimulus.*

The tentacles are not stimulated by contact with food. Several of my experiments show this. A Caravella was in a glass jar and the ends of its long tentacles formed a tangled mass at the bottom of the jar. On this mass of tentacles there was quietly laid a piece of fish. There was no reaction. By the usual occasional contractions of the tentacles they were gradually drawn out from under the piece of fish, but none became attached to it. The same experiment was tried with a piece of shrimp, with the same result. A small minnow, 4 cm. long, was put into this jar. The minnow struck a tentacle with its head, was seized and the tentacle contracted. But before the fish reached the siphons it ceased its struggles and the tentacles relaxed. After some time it again struggled and the tentacle was partially retracted, but the minnow again becoming motionless, the tentacle again relaxed. The minnow lay for a good while motionless on the mass of tentacles at the bottom of the jar; the hold of the tentacle was gradually loosened, and at length the minnow swam quietly away.

The siphons, on the other hand, are stimulated by proteids or, at any rate, by something in animal substances. In order, however, to react to this stimulus, the siphon must first have its mouth in close contact with the food. To test this, I held a number of small objects so that they would come in contact with the mouths of siphons. The siphons would attach themselves to almost anything, but when attached to a piece of fish or mutton the mouths would spread over the object and the siphons would repeatedly contract so that other siphons could become attached. If, on the contrary, the object was of inorganic material, as a piece of glass or shell or a small stone, the mouths of the siphons would not be widely spread over it, and they would soon detach themselves from it.

(*b*) *Mechanical Stimuli.*

Scratching the float with the point of a needle causes a local contraction of the muscles. Squeezing the float with the hand produces a contraction of the whole animal. A strong stimulation of the peduncles of the tentacles or of the cormidia is followed by a general contraction.

Stimulating the peduncle of a tentacle causes it to be wholly retracted, and the same result follows any pull on the tentacle. Gently pushing the tentacles or the whole animal about with a glass rod has no effect, but if a tentacle is wound around the rod and then the rod quickly moved away from the animal, the tentacle is contracted. The results of stimulating the tentacle are not very definite. Pinching the tentacle is sometimes followed by its total withdrawal; more often the effect of the pinch is merely a local contraction, or it may be a contraction progressing downward from the point stimulated. Often in the case of a total contraction a small contraction may be first observed at the point of stimulation, then the larger contraction may be seen to start from the peduncle and quickly involve the whole tentacle. The effect is the same whether the chain of cnidonodes or the muscular part is irritated.

(*c*) *Effect of Wind and Rain.*

I was told by fishermen that the Caravella will erect its crest when the wind blows (see note). To see if this were so, I tried the experiment of directing a stream of air, by means of a pair of bellows, against the float of a fresh specimen in one of the large tanks. The first effect was a general shortening of the float, then it contracted on the side toward the stream of air, then on the other side. This squirming motion continued for a few minutes, when by the contraction of the muscles on the left side,—the lea side in this case,—the sail was erected. Soon after the stream of air was stopped the muscles relaxed and the crest was laid again flat on the water. This experiment was repeated several times. On one specimen freshly brought in, the erection of the sail was more prompt. It was accomplished on three trials in 7, 10, and 15 seconds, respectively, after I began to work the bellows. At first the animal would relax very soon, in say 10 or 15 seconds after the crest was erected, the stream of air in the meantime being continuous. After several trials the crest remained erect for 70 seconds, and finally at the last trial I stopped working the bellows after two minutes, the crest being still erect.

In order to see if the float was sensitive to fresh water I made a series of experiments on two specimens. These were sprinkled by hand with fresh water. The effect was similar to that produced by the current of air, except that in one specimen the contraction of the muscles was much stronger. Between the sprinklings with fresh water, the animals were sprinkled in the same way and with the same quantity of sea water, and remained perfectly quiet. The movements of the float described in the first section of this paper may be due to an irritation caused by the drying of its surface.

EFFECTS OF SECTION.

The immediate effect of section is a strong local contraction sometimes accompanied by a contraction of the whole animal. After recovering from the shock, the severed parts show their normal spontaneous movements and respond in the usual way to stimuli. One of the large tentacles was cut off with its peduncle and suspended in a jar of sea water, it there exhibited its normal movements, but was not very active. It was then cut in two and spontaneous movements were observed in both parts, but they were much less marked in the distal part. Parts that break off spontaneously will remain active for a long time, 21 hours or longer. A number of the detached siphons were cut in various ways. All the parts, even the smallest, about one mm. long, were found capable of moving spontaneously. A float with all the tentacles and cormidia removed, only the stumps of the peduncles remaining, showed likewise its normal power of movement.

Secretions.

Four different fluids, at least, are secreted by Caravella.

1. The surface of the float is covered by a mucous secretion. This is quite apparent to the hands in fresh specimens.
2. There is a very viscid fluid secreted at the mouth of the siphons, by which they first attach themselves to foreign bodies. A thick drop of it may generally be squeezed out of the mouth of a siphon.
3. The siphons secrete a digestive fluid, as is evident from the effect produced on food substances.
4. The cnidocells secrete a poisonous fluid which produces a very painful sensation on the human skin and causes a temporary paralysis in a small animal, and finally in some cases death.
5. There may be added to this list the gas contained in the pneumatocyst, which is probably a secretion.

Senses.

The sensibility of the animal under consideration is very low. Impulses or sensations may be transmitted from one part to another, as is shown by the effect of a severe stimulus and by the action of the float under the influence of a stream of air. It is difficult, however, to see how there can be any real senses without a central organ to preceive the sensations, and I find no evidence of such a structure except that the waves of contraction of the tentacles appear to start normally from the peduncles. This indicates at least a motor centre, but my experiments are not at all conclusive.

I could not find any evidence of a sense of smell. A piece of freshly killed fish was suspended for half an hour within half an inch of a cluster of siphons without their seeming to perceive it in the least. Repeatedly I presented the fish as near to the siphons as I could without touching them, with no effect. Touching the side of the siphons with the fish was followed by no response, but if the fish was allowed to come in actual contact with the mouth it was held fast. A small stone and a piece of apple soaked in sea water were held close to the mouths of the siphons. None were attached to the apple, but after a few minutes three siphons became firmly attached to the stone and remained attached for fifteen minutes, then the stone was allowed to fall.

The siphons seem to discriminate in a slow sort of way between what is food and what is not; spreading themselves out over the former, and soon letting go of the latter. This may be due to a sense of taste, or to the chemical stimulus of the food or of the first products of its digestion. Eyes and ears are absent.

Summary.

As is indicated by the title, this paper does not pretend to be a complete exposition of the physiology of Caravella. Nevertheless, it may be well for the sake of clearness to sum up now in a short account of the mode of life of this animal the chief points indicated by the observations here recorded.

In *Caravella maxima*, then, we have an animal without any sense of sight, hearing, or smell; and with little or no sense of taste or touch. It has only a trace of coördination in its movements, in which there is a certain amount of rhythm, and every part is capable of originating an impulse. Impulses, however, arising in one part may be transmitted to another part. This animal floats on the surface of the ocean and is passively carried about by the winds and currents. The only active part that it can take in its locomotion is to erect its sail when a breeze strikes it, or to heave to in a gale with its tentacles deeply extended into the water. If it rains, the float may be turned over so as to wash off the irritating fresh water.

For food this animal captures small fishes. It floats there on the sea, quietly waiting for some heedless individual to bump its head against one of its tentacles. The fish, on striking, is stung by the nettle cells and fastened, probably by them, to the tentacle. Trying to run away, the fish pulls on the tentacle. The tension on its peduncle, thus produced, acts as a stimulus on apparently some centre there, which sends an impulse along the tentacle that causes it to contract. The fish in this way is drawn up so that it touches the sticky mouths of some of the squirming siphons, or feeding polypoids. As soon as the mouths, covered as they are by a gluey substance and provided with nettle cells, touch the fish they stick fast, a few at first and gradually more. The mouths open and their lips are spread out over the fish until they touch, so that by the time he is dead the fish is enclosed in a tight bag composed of the lips of a dozen or so of siphon mouths. Here the fish is digested. As it begins to disintegrate, partially digested fragments are taken into the stomachs of the attached siphons. When they become gorged they detach themselves from the remains of the fish, the process of digestion is completed in the stomachs, and the nutrient fluid is distributed through the hollow pedicels and peduncles to the other parts of the animal, or, in more technical language, to the other members of the corm.

Note.—While employed on board the U. S. F. C. schooner Grampus during the past summer I was able to make a few observations on this interesting animal while it was still in the warm water of the Gulf Stream. These show that in observing specimens taken near shore one must allow for a certain amount of debility. The animals when we sailed by them in the Gulf Stream, instead of having their crests lying flat on the water as in the tanks at Woods Holl, usually held them erect. When they were relaxed it was only for a very short time. The colors of the animal are much deeper and more brilliant than in the Woods Holl specimens and the poison of the tentacles was many times more virulent, as I found to my personal discomfort. In my experiments in feeding the Caravella I only used medium sized minnows. Mr. Conley, Second Mate of the Grampus, informs me, however, that on fishing vessels it is common when they come across a Portuguese Man-of-War to put the animal in one of the small boats which is filled with water on deck and then throw in full grown mackerel freshly caught, in order to see the resulting struggle, and that the Caravella easily captures the fish. Mr. Conley also said that he was made very ill by picking up the first specimen that he saw, so much so that he was unable to work for several days afterward. His hands at the time were sore from the chafing of fishing lines. I found that the merest touch of the back of the finger to one of the tentacles of these Gulf Stream specimens would produce the most intense pain.

Preliminary Notes on Some New Species of Squilla.

By R. P. Bigelow.

(Published by permission of the U. S. Commissioner of Fish and Fisheries.)

The Stomatopods taken by the U. S. F. C. Steamer Albatross, on her cruise to the Pacific in 1887–88, and during her subsequent work in that ocean, were turned over to Dr. Brooks for study, and he has asked me to undertake this work under his supervision. I am alone, however, responsible for the details of the work, and therefore for errors, if any occur.

So far, I have confined my attention to the specimens of Squilla, and while studying these I find it convenient to make a complete rearrangement of the species of that genus as it is defined by Dr. Brooks in his report on the Stomatopods of the Challenger. It would be premature, however, to publish that until the collection is finished. Of the Squillas received up to this time there are five species, of which all but one are new, and the purpose of the present paper is to give a brief preliminary description of these.

Squilla polita n. sp.

The eyes are of moderate size and triangular. The dactylus of the raptorial claw is short and has four stout teeth; the rostrum is ovate and without carinae. There are no carinae on the caripace except on the posterior lateral lobes, which are evenly rounded in outline. The anterior lateral angles are acute. The cervical suture is obsolete or entirely wanting on the median line. The marginal spines of the second thoracic segment, following Dr. Brooks' terminology, are broad and blunt and curved forward. The lateral margins of the third and fourth segments are rounded without spines. There are no submedian carinae on the dorsal surface of the thorax or abdomen, except on the sixth abdominal segment; the telson has its dorsal surface ornamented by a median crest and a few symmetrically curved lines of shallow pits. There are six large marginal spines, of which the submedian pair are jointed. Of the secondary teeth there are,—submedian 2–3, intermediate 9–12, lateral 1. There is a very conspicuous rounded tooth on the outer side of the inner process of the prolongation of the basal joint of each uropod.

The whole dorsal surface has a highly polished appearance, that suggested the name that I have given to this species. It is closely related to *S. Desmarestii* Risso, from which it differs chiefly in the form of the raptorial claw and of the telson. There are a few specimens from the coast of Lower California and from off Santa Rosa Island, California.

Squilla parva n. sp.

The eyes are rather small and are narrowly triangular, the long axis of the corneal part being shorter than the longitudinal axis of the whole eye. The dactylus of the raptorial claw has six teeth. The rostrum is sub-triangular, with slight median and marginal carinae. The caripace is provided with five longitudinal carinae; the anterior lateral angles are acute, and the posterior ones evenly rounded. The marginal spine of the second thoracic segment is very short, and is obtuse and flattened antero-posteriorly. The margins of the third and fourth segments are distinctly two lobed, the lobes being rounded and without spines. Submedian carinae are present on all the segments of the hind body. The telson has a crest and a symmetrical arrangement of curved lines of pits on the dorsal surface. There are six marginal spines and a pair of anterior lateral carinae. The secondary teeth are,—submedian 3–4, intermediate 7–8, and lateral 1. The tooth on the outer side of the inner process of the basal prolongation of the uropod is prominent.

This description is from a few small specimens from Panama Bay, that I was at first inclined to regard as young of the next species, but there are a number of specimens in the collection of the same size that are distinctly different from these, and evidently do belong to the next species. Those classed under *S. parva* are chiefly distinguished by the much smaller eyes and the form of the lateral margins of the thoracic margins.

Squilla Panamensis n. sp.

The eyes are broadly triangular with a slender stalk. The dactylus of the raptorial claw has six teeth. The rostrum is ovate and provided with median and marginal carinae. There are five carinae on the caripace; the anterior lateral angles are produced into small spines while the posterior lobes are obtusely angled at the sides. The second thoracic segment has a pair of stout marginal spines curved forward and acute. The margins of the next two segments are obscurely bilobed, and the much the larger posterior lobes are obliquely truncated and acute. There are submedian carinae on all segments of the hind body. The telson has on its dorsal surface well marked curved lines of pits on both sides of the median crest, and there are similar pits on the ventral surface. There are six marginal spines all ending in carinae, and a pair of anterior lateral carinae. The secondary teeth are,—submedian 4–6, intermediate 10–11, lateral 1 or rarely 2. The lateral and marginal carinae of the abdomen and the carinae of the telson are thickened in males.

This species is closely related to *S. mantis*, *S. empusa*, and *S. nepa;* especially to the first two. Of these four, *S. nepa* is easily distinguished from all the rest by the strongly bilobed thoracic margins. *S. panamensis* has the two spines on each side of the second thoracic segment widely separated, as is usual in Squilla, and on the margins of the third and fourth segments the anterior lobe is very small. This species is most easily distinguished from *S. empusa* by the more narrow rostrum, the thickening of the carinae in the males, and by the greater number of secondary teeth on the telson. The difference from *S. mantis* that would be first noticed is the curved marginal spine on each side of the second thoracic segment. In *S. mantis* it is short and straight.

This species is apparently very abundant in the Bay of Panama. There are two other groups of specimens in the collection that are distinct from these, but the differences are so slight that they may all be regarded as varieties of one species. First, there are a number of specimens from off Cape Lobos, Mexico, and from Point San Fermin to Couraz Rock, Lower California, that are evidently of the same species as those I have described as *S. Panamensis*, but which differ from them in having the marginal spine of the second thoracic segment more curved, and the anterior lateral carinae of the telson are produced into short spines, so that there are eight marginal spines on the telson.

The other variety is represented by a few specimens from south-east of Tiburon Island, Mexico. It agrees with the first in that the telson has but six marginal spines, while it differs from this and agrees with the last in having a well marked tooth upon the outer side of the inner spine of the basal prolongation of the uropod, and it differs from both the others in having the proximal segment of the exopodite not longer than the distal segment. The marginal spine of the second thoracic segment is large and curved forward into a strongly sickle-shaped acute process. The margins of the next two segments are on the other hand directed farther backward and are more sharply acute than in the other varieties. This variety is also very different in its color marking, if we may judge from alcoholic material.

Squilla biformis n. sp.

This is a well marked species, and the animals grow to a considerable size. The eyes are large and nearly T shaped, the corneal part being very conspicuous. The dactylus of the raptorial claw is armed with six teeth. The rostrum is ovate, with median and marginal carinae. The carapace has the usual five carinae well marked. At the anterior lateral angles the lateral carinae are continued abruptly each into a small spine. The posterior lateral lobes are angled at the sides. The marginal spines of the second thoracic segments are broad, curved forward at their tips, and acute. The margins of the next two segments are obliquely truncated and acute. There are submedian carinae on all the segments of the hind body. The telson is the most characteristic feature of the species. It is large and rather flat, with hardly any elevations on the dorsal surface except the long median crest which ends in a very small spine. Both the dorsal and ventral surfaces are ornamented by very many symmetrically curved lines of shallow pits, and on the ventral surface there is a very short keel prolonged into a stout spine that points directly backward. There are six rather small marginal spines and a pair of anterior lateral carinae. The secondary teeth are,—submedian 5–7, intermediate 15–19, lateral 1. In the female there is very little elevation at the bases of the spines and teeth, while in adult males there is a broad, evenly rounded, continuous ridge around the whole dorsal margin of the telson. This is accompanied by a thickening of the crest and, as in *S. Panamensis*, of the lateral and marginal carinae of the abdomen. Young males resemble females. There are five large adults and two young males from the Gulf of California, off La Paz Harbor. This species is sharply distinguished from all others by its peculiar telson.

Squilla armata, Milne-Edwards.

A number of specimens from both the east and west coast of Patagonia correspond to Miers' description of certain British Museum specimens that he rather doubtfully attributes to this species of Milne-Edwards. There is little doubt that these specimens are of the same species as those described by Miers, but it may be well to supplement his description in some points. The eyes are broadly triangular; the teeth on the dactylus of the raptorial claw vary in number from seven to nine. One specimen had six on one claw. On the posterior margin of the fifth abdominal segment on each side, midway between the submedian and intermediate carinae, there is a group of from two to four small spines. The line of tubercles that Miers speaks of as running along each side of the crest of the telson is hardly to be made out, but both the dorsal and ventral surfaces of the telson are ornamented by the usual curved lines of shallow pits. There is little or no trace of anterior lateral carinae. The submedian spines are jointed, the distal, movable portion being, however, very small. Teeth,—0, 10–11, 1.

This species has many resemblances to *S. polita* n. sp., the chief differences being the somewhat larger eyes, the greater number of teeth on the raptorial dactylus, the acute thoracic margins, the submedian carinae on the hind body, and the larger telson with relatively shorter spines and less prominent crest.

The Anatomy and Transformation of Tornaria. A Preliminary Note.

By T. H. Morgan.

The larva of Balanoglossus—Tornaria—found on the New England coast, has been figured excellently in Agassiz's classical paper on Balanoglossus and Tornaria (1873). He referred the larval Tornaria to the common species of Balanoglossus Kowalevskii, found on the same coast. During the past summer (1890) I had an opportunity, while enjoying the facilities of the Boston Marine Laboratory, to study the same Tornaria, which occurred there abundantly during August. At the time, a careful study of Balanoglossus Kowalevskii put me in a position to examine into the supposed relationship between it and the Tornaria. The conclusion reached was that the Tornaria is not the young of B. Kowalevskii.

This clears up the difficulty which Bateson met in his study of B. Kowalevskii of the Chesapeake. In this he found no Tornaria stage, but the egg developed by a direct (abbreviated!) development into the adult worm. Recognizing the identity of the northern species of B. Kowalevskii to the southern form, it became evident either that one had a free swimming stage and the other a direct development, or that a mistake had been made by Agassiz. The latter, I believe, is the true explanation, and for the following reasons: The time of maturation of the eggs of B. Kowalevskii seemed to be at Woods Holl, Mass., a little later than the earliest appearance of Tornaria. The Tornaria came suddenly and in great numbers, and were of all ages. The numbers gradually diminished, then disappeared entirely. At the time of occurrence there was a decided change in the nature of the tow-stuff, notably in the presence of many small hydro-medusae of half a dozen species, of several Loven's Larval (Polygordius), of young Ctenophora, &c. Many or all of these must have come from outside, and have been blown or carried in by marine currents. These, like the Tornaria, remained for a few days, then disappeared. Finally, and I believe this is conclusive in itself, the youngest Tornaria which were caught were only about two-thirds as large as the mature eggs of B. Kowalevskii; the eggs themselves correspond in size *exactly* to those described by Bateson in the southern form. It seems to me absolutely impossible that the large egg of B. Kowalevskii filled with yolk could give rise to the smaller transparent Tornaria with no yolk in its digestive tract.

The free swimming Tornaria undergoes many changes both in size and structure during its pelagic life. In the smallest individual captured the ciliated bands were not nearly so complicated as in the later stages. In it there is a small anterior enterocoel opening to the exterior by a small pore to the left of the mid-dorsal line, and the two paired (more posterior) enterocoels were in no way represented. The characteristic, circular, ciliated band encircling the embryo in front of the anus was developed. The anterior longitudinal band may be reduced, I think, to a single circumoral band, as in the echinoderm larva, though in older forms this, as in the echinoderm, tends to break up into two bands. Where the bands bend over the anterior of the embryo they unite with the apical plate. The latter is a thickened mass of ectoderm with two small eyes imbedded within it.

Two important changes next take place in this larva, as it increases in size, namely, the appearance of the two posterior pairs of body cavities and the formation of a mass of cells in the region of the opening of the water-tube. These latter are the cells which Spengel described as originating from the ectoderm, subsequently passing in and connecting with the anterior enterocoel to form the heart. This statement does not seem correct. In the first place the solid mass of cells arise *in contact with the ectoderm*, but I think not from it, but come from some mesenchyme cells which are attached to the inner surface of the ectoderm above and somewhat to the right of the water-pole. Later this cell mass moves inwards, the cells arrange themselves around a central cavity, and the vesicle then applies itself to the anterior enterocoel between its two horns. The heart is formed between this vesicle and the enterocoel, its cavity is continuous with the general blastocoel cavity of the larva, and its walls formed in part by the enterocoel and in part by the vesicle. The cavity within the mesenchymatous vesicle is the cavity of the proboscis gland (Bateson).

The first pair of paired body cavities *do not originate as folds from the gut*, but a proliferation of cells forms a thickened mass at two opposite areas of the mid-gut. These cells afterwards arrange themselves around a central cavity and the body cavity arises by increase in number of these cells. The second pair of paired body cavities arise from a *solid fold* at two opposite points of the posterior division of the mid-gut, which very early pinch off from the endoderm. A cavity then appears and subsequent growth is entirely, as before, from these few cells. Figures are necessary to make clear these details. The important point is that the body cavities do not originate as open gut pouches, although there would seem to be no real difficulty, if it seemed necessary, in referring the process back to some such type.

As the larva increases in size the anterior ciliated band becomes folded in its characteristic way. A change takes place in the region of the apical plate, so that the bands are broken, leaving four free ends, which tend to break the previously single band (or so I think we may regard it) into two bands.

The two eyes are not simple pigment spots, but well defined structures. Each is semi-circular in shape, with a crescentic row of clear cells, each cell ending towards the concave side in a sharp spine-like process. The different spines point towards the centre of the circle, of which the whole eye represents but half. On the convex side of the crescent the clear cells disappear in a pigment zone, and in this zone lie their nuclei. Three pairs of gill pouches appear seriatim but almost simultaneously; and later before metamorphosis, a small fourth pair arises.

The larva changes somewhat its shape and sinks to the bottom of the dish. There is a decided decrease in size at this time, accompanied by a thickening of the ectoderm over the whole embryo, and by the disappearance of the anterior ciliated band (or bands). The diminution in size at this time is very similar to the process found in echinoderms just prior to their metamorphosis. During this period an important change, as noticed by Agassiz, takes place in the digestive tract. The whole anterior part becomes pulled backwards (tailwards), as it were, so that the gill pouches lie in a more posterior plane of the body, opposite the place at which the gill pouches subsequently break through. The "notochord," likewise, which appeared close to the mouth opening, is also pulled inwards and comes to lie in close contact with the anterior enterocoel. The walls of this enterocoel have thickened greatly and begin to encroach upon the cavity of the organ. In the region of the heart the enterocoel wall becomes filled with blood from the heart and projects somewhat into the enterocoel cavity.

But the most important change that occurs during this period is the development of the nervous system in the collar region, as is shown very clearly in serial sections. Before the loss of the ciliated bands a groove appeared around the embryo below the lower limb of the anterior band, and this groove marks the posterior limit of the collar. In the mid-dorsal line the continuity of the groove is broken. A careful examination shows that here a plate of ectoderm is sinking below the surface, and at the same time *the collar is rolling over the invaginating plate of ectoderm from the two sides.* It is clearly seen that the nervous system originates in this region precisely by the same process that takes place in Amphioxus, *i. e.* the ectoderm from the two sides rolls over a median plate and fused above it, and the edges of the plate do not take part to any great extent in the rolling up of the ectoderm. Posterior to this region the nerve chord is formed by much the same process, although the plate is smaller. The growth of the nerve chord forward, in the later stages, takes place I think by a fusion from time to time of the under surface of collar to the upper surface of the base of the proboscis, and thus arise those curious stellate structures found throughout the chord of the adult Balanoglossus.

The second and third paired body-cavities grow much larger and apply themselves to the ectoderm and where they meet in the mid-dorsal and mid-ventral planes there is enclosed between them a large blood space. The mid-dorsal tube unites anteriorly with the so-called heart of the proboscis, so that the whole becomes a continuous tube. The heart we saw was formed between the anterior enterocoel and the mesenchyme vesicle. Whether or not this vesicle is homologous with a body-cavity or a part of such, I am not prepared to say. It must not be forgotten at any rate that the walls of the heart are formed by the application of two vesicles—the mesenchymatous vesicle and the enterocoel—just as the other blood vessels are formed by the contact of the body-cavities of the two sides. In a larva kept seventy hours the posterior part of the body-cavity had elongated greatly and the whole posterior extension of the body contains a sac which is the extension posteriorly of the last pair of body-cavities. This I think is an important fact to be remembered in phylogenetic considerations of the group. It is also interesting that these body-cavities are *secondarily* filled with a mesenchymatous tissue.

From Dr. H. V. Wilson I have received some larvae of the large Bahama Tornaria, which were collected when the Johns Hopkins Marine Station was located at Nassau. These are undoubtedly the same larvae that Weldon has described from the same locality. Those I have were collected in May, his in October. Weldon made an unfortunate blunder in his interpretation of the larvae. He described for the youngest stages the small Balanoglossus which had just undergone its metamorphosis, and believed the Tornaria which he found (and which were about ready to undergo a metamorphosis) to be those young which had been pushed out into deep water and then developed differently. Later Weldon himself corrected the error. Dr.

Brooks tells me that the Tornaria which he collected at Nassau underwent the usual metamorphosis, changing into the young Balanoglossus described by Weldon.

The arrangement of the ciliated bands in the Nassau larva are remarkable, but a careful examination has shown that they conform exactly to the simpler arrangement of their northern relative. The course of the bands is obscured because the whole (or nearly all) of the ciliated band is drawn out into a series of lappets or frills, thus increasing enormously the amount of ciliated surface. In the second place, the somewhat bilateral arrangement of the bands of the northern form has passed into a perfectly radial arrangement in the Nassau species, due to slight alterations in the positions and lengths of the bands. The other parts of interest in this larva need not be described here. The similarity of Tornaria to the Echinoderm larva are very numerous, and I cannot believe are due to superficial resemblances. If this be true, the antiquity of the larva must be very great, though not necessarily ancestral. The relationship of Balanoglossus to the Vertebrates seems more than probable, as Bateson has pointed out. In a forthcoming paper I hope to discuss these questions more fully.

The Distribution of Magelona. By E. A. Andrews.

In a letter to Professor Grube, published in the *Archiv. f. Naturgeschichte*, 1858, Fritz Müller describes a remarkable Annelid taken at the island Santa Catharina, off the coast of Brazil. It has the following peculiarities: two long tentacles bearing papillæ such as no other Annelid has; the presence in the posterior region of the body of dorsal as well as ventral clusters of hooked setæ; a curiously flattened, expanded, cephalic lobe. He gives figures and descriptions of the hooked setæ, of the nephridia and of certain characters of the vascular system, and proposes for this isolated form the name *Magelona papillicornis.*

A few years later Ed. Claparède found on the coast of Normandy, at St. Vaast, remarkable Annelid larvæ, excellently described and figured in his *Beobachtungen*, 1863. These he refers without doubt to Magelona, though the adult was then unknown in European waters.

In Great Britain, however, the adult had been observed even before this date, and its resemblance both to the Spionidæ and to the Chætopteridæ had been pointed out. Yet its structure was not exhaustively studied till McIntosh, in 1878, wrote a paper in the *Zeitschrift f. wiss. Zoölogie*, dealing both with its external and internal anatomy. Referring the animal to the Spionidæ he also showed its affinities to the Chætopteridæ, the position of this latter family becoming thus a less isolated one.

The next notice regarding the occurrence of Magelona is to be sought in the figures and description of larval forms taken at Newport, R. I., by W. Fewkes. In this paper (*Bull. Mus. Zoöl.*, Harvard, 1883), the larvæ regarded as possibly the young of *Prionospio tenuis*, Verr., are undoubtedly young Magelona.

Giard, in 1886, states that the adult Magelona is common at Wimereux, France, and that larvæ, which may be traced to an adult Magelona condition, are identical with the above larvæ, erroneously referred by Fewkes to Prionospio. Giard, however, refers Magelona to the Chætopteridæ.

One of the more abundant Annelid larvæ taken at the surface at Beaufort, N. C., in 1884 and 1885, was an undoubted Magelona, agreeing so closely with those obtained by Claparède as to leave little doubt that it belongs to the same species. These young forms are well fitted for a prolonged pelagic life, having large clusters of defensive provisional setæ, extraordinarily long tentacles, a mouth capable of engulfing the large veligers frequently found within the capacious digestive tract, and a transparent body provided with yellow pigment areas and red eye-spots.

The adult has not been recorded from the coast of North America. Last summer, however, a single individual was discovered with Spio and Nephthys in the flat of pure sand north of "The Neck," Woods Holl, Mass. This specimen measured about 25 mm. by ½ mm., and was translucent except for the opaque flake-white, anterior region, tentacles and the sides of some posterior somites that contained conspicuous eggs.

The intestine showed some dark green-brown color, and a few minute pigment specks were observable upon the tip of the cephalic lobe, as well as at the bases of some of the papillæ of the tentacles. These tentacles measured 12 mm., the cephalic lobe 1½ mm., while the proboscis was evaginable half the latter distance. The animal covered itself, in a few hours, with a tube of firmly adhering sand grains.

Subsequent examination revealed the same structure in setæ, parapodia, nephridia, etc., as given in the account by McIntosh for *M. papillicornis*, so that there is no doubt this species occurs upon the New England coast.

The wide distribution of the adult Magelona, living as it does buried in the sand, is to be explained by the long duration of a pelagic larval stage capable of transport by ocean currents.

It is possible that the above specimen was a chance importation, and does not represent a permanent residence of this animal on our Northern Atlantic coast. Yet the occurrence of larvæ at Newport, and the large eggs found in the Woods Holl specimen in August, would indicate a more than temporary existence of the species here.

Moreover the small size and inconspicuous, almost protective, coloration of the animal, in pure sand, would explain its having hitherto escaped attention even where so careful an examination has been made of the Annelid fauna.

Time of Flowering of Hepatica triloba. By Basil Sollers.

In the preparation of a Local Flora, the time of flowering of each plant is an important consideration. For the past few years I have given particular attention to this subject, and especially to the latest Fall and earliest Spring flowers. I am satisfied that many interesting facts in this connection escape the notice of botanists, because of their too great reliance upon the dates given in the manuals. In the hope that it may prove interesting to others, I have written out some results of observations I have made upon *Hepatica triloba.* This plant is found from Maine to Florida. Its time of blooming as given by Gray is "soon after the snow leaves the ground in Spring," while Chapman, the northern limit of whose work is North Carolina, puts it at February–March. Wood says it is "one of the earliest harbingers of Spring."

Ward's Flora of Washington and Vicinity contains a list of Spring plants found at early dates, in which is *Hepatica triloba*, found February 20th, 1876. In the vicinity of Baltimore, I found it blooming March 19, 1886; March 10, 1887; February 26, 1888; and January 8 and 13, 1889. The differences here indicated are probably not due to differences in the seasons, but to the fact that I had not thought to look for it so early in the first years, and was not acquainted with the most likely situations to find it in bloom. Last year I found it December 25, January 3, February 16, and in fact whenever I looked for it, and each time I was able to get a dozen or more flowers in the few square yards of my favorite situation. But the season last year was extraordinary. Some of the plants found December 25 had already gone to seed, which led me to expect a still earlier date. This year I looked for Hepatica first November 8th, and was again too late to get the earliest blooms, since the two specimens which I found had already lost their petals. They had been in bloom at least as early as the last week in October. November 19th I found two fresh blooms, which had come out since November 8th.

When the flowers of Hepatica come out in Spring, the last year's leaves are still present, but apparently functionless. The new leaves are developed and perform their work during the late Spring and Summer months, resulting in the production of one or more buds in which are contained the rudiments of next year's development.

If these buds be examined at this date (November 24), they are found to consist of from five to seven scales enclosing each other, and under each, except the first one or two, will be found a flower bud on a scape a quarter of an inch or less long, the whole being densely covered with long silky hair, which must afford much protection during severe weather. In the centre, covered by the flower buds and their protecting scales, the rudiments of next year's leaves are found, also thickly covered with long, straight hair. The outermost flower blooms first, and when there is a lack of warmth, seems to appropriate to itself all the activity of the plant, lengthening its scape to one or two inches, coming into bloom and perfecting its fruit while the other flowers remain snugly covered by their protecting scales. Sometimes a second bud will burst from its scale before the first has run its course. The scape in these Fall and Winter flowers is always shorter than in those that bloom in the Spring. Sometimes it is very short, the flower expanding when the scape has lengthened only sufficiently to free it from the scale. November 8th I found a plant on which was a flower bud whose scape had lengthened about an inch and raised it above the scale. November 19th I examined the same plant and the same bud. The scape had lengthened to two inches and the flower had just opened. A second flower bud had burst from its scale, and was on the point of opening with a scape considerably less than an inch in length. In April and May all the flowers of a given plant may be found in bloom at the same time.

To sum up, *Hepatica triloba* may be found in bloom at this latitude, in favorable situations and favorable seasons, during the months of October, November, December, January, February, and March, in addition to April and May, when its most plentiful bloom occurs.

Notes on the Habits and Larval Stages of the American Lobster. By F. H. Herrick, of Adelbert College.

These notes are the result of studies made during July and August, 1890, at the laboratory of the U. S. Fish Commission, Wood's Holl, Mass. A study of the development of the lobster, *Homarus americanus*, was begun in the spring of 1889, upon embryological material kindly furnished me by Mr. George H. Parker of Harvard University. The work was continued during the following summer, and has since been renewed under the auspices of the Fish Commission, with the intention of preparing for the Commission as full a report as possible upon the habits and development of this valuable economic animal.

In a paper published in the *University Circulars*, No. 80, 1890, some statements were made with reference to the breeding habits, which the experience of the past year has shown to be incorrect. The spawning season is confined to the summer months, and the eggs which are then laid, are carried by the female throughout the fall, winter and spring, and are not hatched under natural conditions until the following summer.

The period during which eggs were laid this year (1890) began about July 1st, and extended until about August 20th. Of 82 lobsters which were examined at this time, and which carried newly-laid eggs, 59, or nearly three-fourths of the whole number, had extruded their eggs during the latter part of July (July 21st–31st). Eleven had laid eggs from August 1st to the 10th. On the 19th of August one lobster was found with nearly mature unextruded eggs.

In 1889 the spawning was somewhat earlier. The eggs which I examined, taken from a smaller number of lobsters, were laid from June 20th to July 15th. The age of the embryo can be approximately determined (*cf.* tables in the paper following on the segmentation and early development), and this gives us the approximate date on which the eggs were laid.

Lobsters will not breed readily when confined in close quarters, but probably could be made to breed in suitable enclosures. A female lobster, which we kept in a small aquarium by itself for upwards of eight weeks, laid eggs about August 23d, and was discovered soon after when the ova were in advanced stages of yolk segmentation. These eggs were unusually light in color, but were normally fixed to the abdomen and were undoubtedly fertile, although the segmentation was exceptionally irregular. Surface views and sections of these eggs show a condition of things which is commonly met with in a small percentage of all segmenting lobsters' eggs. This exceptional segmentation is referred to in the accompanying paper. In the course of a few days this lobster scratched off all of her eggs so that their development was not further followed.

I am not aware that the union of the sexes has ever been observed in the American lobster, but we may infer that it is effected in very much the same way as in the Norwegian lobster or in the crayfishes, and that the sperm is deposited at this time by the male upon the under surfaces of the body of the female. It is also probable that copulation precedes oviposition by a considerable period—at least eight weeks in the case of the lobster just mentioned. The eggs when extruded from the ovary are free and enclosed by a single egg-membrane, the chorion, which is secreted gradually during the process of growth of the egg within the ovary by the enveloping stratum of follicular cells. A second membrane, the membrane of attachment, is added to the eggs outside of the ovary. The actual process of egg extrusion has not been witnessed, but in lobsters with newly-laid eggs the ovary contains numerous mature ova which failed of passage, and the oviducts are often crowded with them. We may reasonably infer that the method of fixation of the eggs to the underside of the abdomen is similar to that which has been observed in the crayfish. The supernumerary ova, which are not laid, degenerate, but are not wholly absorbed by the time the ovaries are again ripe. They form the yellow spots which are commonly seen on the ovaries of lobsters which have already produced eggs.

The structure of the vas deferens, which is described in another paper, leads me to suppose that the adhesive substance which is secreted in the glandular part of this organ, is ejected, together with the spermatozoa, during copulation, and that possibly it may serve to fasten the latter to the under surfaces of the body. This glue, when taken from the vasa deferentia, is soft and transparent, but hardens slightly when drawn between the fingers in sea-water.

The number of eggs which are laid varies from about 3,000 to upwards of 36,000, depending largly upon the size of the lobster as is shown in Table I. These numbers are compiled from the record kept by Mr. Vinal N. Edwards. A lobster 10½ inches long produces, on the average 12,000 eggs.

TABLE I.

Length of Lobster in inches.	Average No. of Eggs.	Largest No. of Eggs.	Smallest No. of Eggs.	No. of Lobsters Examined.
8		4,570		1
8½	5,328	6,090	4,566	2
9	7,628	18,270	3,040	55
10½	11,965	21,315	3,045	138
12	19,642	30,450	6,090	22
12½	20,249	24,360	12,180	5
13	21,062	24,360	15,225	6
13½		30,450		1
14	25,882	36,540	15,225	2

The hatching period at Wood's Holl (determined for the seasons 1889, 1890) extends over a period of six to eight weeks, from about May 15th to July 15th. The last lobsters with "light eggs" (eggs of previous summer) were taken by the Gay Head lobstermen, July 7th. This was also the date on which they took the first lobster this season with "black eggs" (eggs recently laid). The eggs of this lobster had been laid about the first of July. (For the history of the development of this lobster's eggs during the fall and winter, see Table II of the following paper). Eggs were hatched at the Fish Commission Station artificially this season as early as May 14th. The bulk of the eggs are hatched under natural conditions in June, and probably during the first half of this month.

The lobster does not breed annually. This is abundantly proved by the slow growth of the ovarian eggs, by the immature condition of the ovaries at the time when the young are hatched, and by the large percentage of non-egg-bearing female lobsters taken in the winter and spring.

In May, 1889, 942 lobsters were taken at Wood's Holl by Mr. Vinal N. Edwards. About ten per cent of these were females with eggs. In June, 2184 lobsters were caught, and of these 1175 were females, 108 of which bore eggs, or about .04 of the total catch. This decreased percentage of egg-bearing females taken in June is due to the fact that the eggs begin to hatch during this month. These and other facts of interest, as the excess of females over males, are shown by the following table which is compiled from the records of the Station.

TABLE II.

Date.	Total Catch.	♂	♀	♀ with eggs.	% of ♀ with eggs.	♂ under 10½ in.	♀ under 10½ in.	♀ over 10½ in. with eggs.	♀ over 10½ in. without eggs.	% of ♀ to ♂	% of ♀ without eggs to ♀ with eggs.
1889.											
April, 24–30.	104	49	55	22	*21*	49	55	0	0	*112*	*150*
May.	942	440	502	185	*10*	418	439	54	9	*114*	*171*
June.	2184	1009	1175	108	*.04*	976	1099	45	31	*116*	*987*

All egg-bearing lobsters taken during the late winter and spring months invariably have light colored eggs or eggs in an advanced stage of development, since in these the yolk which gives to the summer eggs their dark green color, has been largely consumed. The eggs laid in summer develop with comparative rapidity and eye pigment is formed in 27–30 days. Development slows up in fall and comes nearly though never quite to a standstill in winter. (*V.* Table II of following article for a more precise statement).

Soon after hatching a brood the lobster may moult, but eggs are not laid again until at least another year. If the moult does not occur at this time, it may take place in the fall, and possibly at any other period until the eggs are again extruded. It is common to find moulting lobsters in early summer, and I have met with a very few cases in which the moult was passed shortly before the laying of the eggs. In November, 1890, Mr. Vinal N. Edwards, of the Fish Commission Station, observed more moulting lobsters than during all the previous spring and summer months. Lobsters 7–10 inches long increase their length by 1 inch after the moult is passed. This was also true of a lobster 12 inches long. The smaller lobsters came out without cracking their shell, through an opening between the carapace and first abdominal segment. In the living lobster a narrow blue stripe is seen in the dorsal median line, extending from the rostrum to the hinder end of the carapace. This marks the line of dehiscence along which the shell separates ordinarily at the time of moulting.

Lobsters after becoming sexually mature (length 8–9 inches in the female) probably do not as a rule moult annually. After moulting, the new shell hardens quite slowly. Three days after the moult the shell is still leathery and the rostrum and appendages can be easily bent without breaking. The recently moulted lobsters, called "buckle-shells," alias "paper-shells," alias "June" or "Sand lobsters," are most abundant during summer from the middle of June to the middle of July on sandy bottoms in Vineyard Sound in 8–15 fathoms of water. It seems quite probable that there is a considerable movement of moulting lobsters at the middle or latter part of June from deeper to shallower water and often from rocky to sandy bottoms. Large numbers seem to pass from the rock bottoms around Gay Head on to the shallower and sandy bottoms of the Sound. Later, from the middle to the last of August, lobsters appear to be more abundant in deeper water, and the shells of those which have moulted this season, have by this time become tolerably hard. The colors then are much brighter and the shell is less worn than is the case with lobsters which have not moulted during the present season. It probably requires from six to eight weeks to produce after the moult a fairly hard shell which cannot be easily compressed between the thumb and finger.

If the ovaries of the "paper-shells" are examined, they are very generally found to be pea-green in color, and in the immature condition corresponding to that of the ovary of the lobster which has hatched young during the present summer, and I believe that a large proportion of "buckle-shells" represent this class. Rarely "paper-shells" are found with new eggs or mature ovaries. These have moulted, but have not hatched eggs this season. Lobsters are sometimes found in the act of shedding, buried in the sand, in shoal water.

At the time of hatching the young lobster moults, and this delicate moulted skin is often cast off together with the egg-shell. It is of considerable importance, since in artificially hatching lobsters, large numbers die, through inability to pass this moult. After 6–7 days the second moult occurs.

Young lobsters swim at the surface for 6–8 weeks (L. 13–16 mm.) when they attain a stage which resembles the adult in a general way, but differs from it in many details. The large chelæ are similar both in shape and size. The larva both walks on the bottom and swims at the surface of the aquarium. After this stage the lobsters disappear entirely from the surface.

In the adult, I have never observed any variations of color between the sexes, but individual variations are very noticeable, the cast of color of the upper surface varying from reddish-brown to reddish-green, bluish-green and greenish-blue. In the extruded eggs I have never found marked variations in color which could not be attributed to progressive changes in development, excepting in the case of the lobster already referred to, which laid her eggs while kept in an aquarium. These eggs were of a light pea-green color. The color of the normal, freshly extruded ova is a dark, blackish olive, varying somewhat in intensity. The color of the unripe ovarian ova does however vary considerably. The ovaries, when immature, are cream color, yellow, flesh or salmon color, greenish yellow or light olive green. After lobsters have once extruded eggs, there seems to be less variation in the color of the ova, which in the very immature condition are usually light pea-green. In the cases where the eggs are yellow or pinkish in tint, this color is gradually replaced by the green pigment, which is developed in the yolk spheres first in the vicinity of the germinal vesicle, and thence spreads toward the periphery of the egg. Ova in the latter state present an outer yellow zone, a green core, and an intermediate belt of greenish yellow yolk. Where the yolk is never any color but green, the pigment develops around the nucleus first, and thence spreads to the periphery of the egg.

The larvæ, after the first moult, vary remarkably in color; and this variation is noticeable in the embryo for a considerable time before it hatches. Some are bright red, others are greenish-blue, and others are pale blue or nearly colorless. In the red variety, the red color is due to large amœbiform pigment cells, which are distributed chiefly over the sides of the carapace, and on the sides and under surface of the abdominal segments. Yellow pigment also occurs sparingly on the thorax. The blue pigment is very diffuse, and, excepting in the blue variety, is mostly confined to the appendages and joints of the abdomen.

Individual color changes are less noticeable in the young than in the older larvæ. The following change of color, which was almost as striking as that seen in the lizard Anolis of the Southern States, occurred in a young lobster 16 mm. long, taken at the surface July 24th, and left over night in a glass dish on an unpainted pine table. When first taken, this lobster was bright bluish-green all over, a slight amount of brownish pigment being visible. The next day it had assumed a marked reddish-brown hue. Nearly the whole upper surface of the body was sprinkled with light reddish-brown pigment. The appendages also were quite uniformly marked with the same color.

CLEVELAND, OHIO, December 15th, 1890.

The Reproductive Organs, and Early Stages of Development of the American Lobster.

By F. H. HERRICK, of Adelbert College.

The origin and growth of the ovarian eggs of the lobster was briefly described in No. 54 of the *University Circulars*. A fuller account, accompanied with figures, of the ovigenesis of the lobster and other allied forms has been delayed in publication, but since a much richer supply of material has been recently gathered, I will give a resumé of all the facts which I have collected on this subject.

Growth of the Ovaries and Ovarian Eggs.

The ovaries consist of two cylindrical rods or lobes which extend from the root of the rostrum to the 3d–5th abdominal somites. The lobes diverge anteriorly, surrounding the upper part of the gastric mill, and meet on the middle line behind the eyes. They are united by a transverse bridge of tissue in the neighborhood of the heart, and behind this point an oviduct is given off from each ovary. If the greatly distended ovary of the ripe female is cut, the eggs flow out in a stream, leaving a hollow tube of white, spongy tissue.

The structure of the mature ovary is peculiar. The free, unextruded eggs fill the lumen of the ovarian lobes. The lobe or tube itself consists of the proper ovarian tissue and the outer muscular wall, which is very thick. The stroma is characterized by the presence of *gland-like structures*, blood-vessels and immature ova. The glands are in close relation with the growing eggs. They are plaited or folded structures, and consist of a single layer of columnar cells, the boundaries of which are indistinct. The lumen of the fold usually contains a granular residue, but often yolk and degenerating nuclei. It seems probable that these structures are comparable to *yolk glands*, and that their function is to supply the growing ova at this stage with a part of their massive food-yolk. Three days after the extrusion of the eggs the glandular coeca have much thicker walls; the rapidly dividing cells are smaller, and their nuclei lie at various levels. In another ovary of about the same age the glands are relatively very large. The columnar cells are greatly elongated; their nuclei lie at the deeper or outer ends of the cells, and the lumen of the gland is often completely obscured. The gland forms a kind of egg-tube, abutting upon, and partly enclosing the growing egg. The columnar cells stop short at the sides of the egg, so that the glandular coecum resembles a narrow bag with an egg pushed into its mouth. The axial portion of this ovarian lobe is composed of hollow spaces, blood sinuses, and loose stroma, in which very young eggs occur.

When 10–15 days have elapsed after egg-laying (eggs in egg-nauplius stage), the gland-like bodies have almost wholly disappeared. The walls of the coeca are shrunken and crumpled, and the latter have been crowded to the extreme periphery of the ovary. The ovary now contains a solid core of immature eggs, stroma and blood-vessels. This is continuous with radial sheets of similar tissue which extend from the centre towards the periphery. The outer and more mature masses of ova are thus divided into more or less continuous, longitudinal bands. The ovarian stroma is often coarsely reticular, and encloses in its meshes not only developing ova, but homogeneous masses of yolk. In many cases these appear to be degenerate nuclei, and homologous with ova. This yolk does not seem to be taken up directly by the eggs.

At a still later period (eggs with eye-pigment, 4–5 weeks old), the glands are present merely as shrivelled remnants. Later still (lobster taken Aug. 21st, egg-embryos in a late stage), there is no trace of gland-like structures. In the ovary of a lobster (taken June 30th), with eggs about to hatch, the condition is similar to the last. It is now about eleven months since the eggs were laid, yet the diameter of the largest ovarian ova is only about one-half that of the mature eggs. The ovarian wall is thinner than in previous stages, and in the axis of the lobe there are still sheets of very small, immature ova.

It seems that the bodies which have been described as probable yolk-glands, are present in the peripheral parts of the ovaries only during the limited period of from two to three weeks after the eggs are laid, and when the organs are recovering from the changes which follow this event. The structure of these glands is quite unlike that of blood-vessels or sinuses with which they are intricately associated, and their relation to the growing eggs seems to imply that they have some function to perform in the nourishment of the peripheral ova. Their short existence on the other hand, might lead us to suspect that they were more or less rudimentary.

Ovaries which I have examined, taken in summer (July), from lobsters ("paper shells") which have recently moulted and which do not carry eggs, present very thin walls, and the largest ovum measures in diameter about one-half that of the mature egg. These lobsters have probably hatched a brood the present season, and afterwards moulted. (Compare the ovary of the lobster taken June 30th, above). I have also the ovary of a lobster (non-egg-bearing) taken in January, in a similar condition, except that the axial stroma is less differentiated.

Some allowance is to be made for individual difference, but the slow growth of the ovarian egg, which we have traced from the summer when eggs were laid to the following summer when these eggs were hatched, is very noteworthy, and shows conclusively that the lobster is not an annual breeder.

The ovaries are not present as definite structures until at a comparatively late period, although the cell mass from which they are subsequently developed is probably distinguishable in the larvae. In a lobster $4\frac{1}{4}$ inches long, the ovary is a white delicate rod $\frac{1}{30}$ inch in diameter, extending into the third abdominal somite. In another lobster, $9\frac{5}{16}$ inches long, which had evidently never produced eggs, the ovary was only $\frac{1}{17}$ inch in diameter. The structure of these very immature ovaries is similar to that of later stages. The walls are quite thin. "Glands" are absent. The cells of the axial stroma divide by karyokinesis, and give rise to new ova, the largest eggs lying next to the outer wall.

Origin of the Ova.

The germinal vesicle of the ovarian ovum is the direct descendant of the ovarian nuclei, or nuclei of the stroma. The yolk appears to be formed at first within the meshes of the protoplasm of the ovum, which is clearly marked off at an early stage, from the general matrix in which nuclei of the stroma are embedded. It seems probable that yolk is also formed by the "glands" which have been described, and from degenerate cells in connection with these structures, and from degenerate nuclei in various parts of the ovary. The germinal vesicle acquires at a very early stage the characteristic nucleolus. Each egg soon becomes invested by a layer of follicle-cells, derived from the general ovarian stroma. From this cell-stratum the chorion is gradually formed. The relation of the glands, which resemble egg-tubes, to the growing ova has already been described. As the eggs increase in size they gradually pass outward towards the wall of the ovary.

Structure of Testis and Vas Deferens.

The testis is a slender, white, sacculated body, extending from the first thoracic to the third or fourth abdominal somites, and giving off a vas deferens at a point about one-third of the distance from its anterior end.

The vas deferens consists of three sections, a proximal slender portion, with relatively thin walls, which terminates abruptly in a median, very large, eminently glandular section. There is a prominent sac-like enlargement at the end of this portion, which passes into the terminal muscular division.

The testis itself is composed of saccules filled with spermatoblasts, from which the sperm is developed. The ripening sperm from neighboring compartments flows together and forms an axial stream, which passes into the first section of the vas deferens, where it is surrounded by a thin layer of viscous, homogeneous material. The exhausted parts of the testis become lined with a definite layer of epithelium. In the glandular section the current of sperm is enveloped in a larger mass of viscous matter. The muscular part of the vas deferens has very thick muscular walls and a prominent lining epithelium.

It seems probable that the viscous substance may be expelled with the sperm, and that as already conjectured, it may serve to fasten masses of spermatozoa to the under surface of the female, during copulation.

Segmentation of the Nucleus and Yolk.

Normal segmentation of the yolk as it appears in surface views of the living egg will be first described. The time occupied in the segmentation processes is shown in the table below. There is great irregularity in the segmentation and lack of uniformity in the rate at which this process proceeds in perfectly normal eggs, or eggs which eventually develop in a normal fashion. Some eggs which afterwards develop, remain with yolk unsegmented until the third or fourth day after fertilization. Small spherules of yolk are seen at a very early stage beneath the chorion, suggesting often polar bodies in general appearance, or that such bodies have been liberated in connection with them.

The protoplasm reaches one side of the egg first, that side from which the chorion is distinctly elevated, and the cells, 3–4 in number, can be seen shimmering through the dark green yolk, before the nuclei can be detected. Eventually nuclei are seen, which soon divide by karyokinesis, and spread over a greater area of the surface. The nuclei, though not quite at the surface, appear to be so, and the yolk amasses itself about them in the form of hillocks. These constitute the first yolk segments or pyramids. A profile view of the egg shows a perfectly regular contour on one side, while on the other it is thrown into undulations, which correspond to the segments just noticed. The lobster's egg at this stage thus strongly recalls the meroblastic type, and would seem to represent a transition between this and the ordinary superficial segmentation of Decapods. This, however, is not quite true, as will be presently seen. Nevertheless, it presents an interesting variation from what occurs in Alpheus Saulcyi, for instance, where eight cells are formed and pass to various parts of the surface. Upon the next division of these cells in Alpheus, sixteen yolk pyramids appear to be formed almost immediately.

Cells not only spread over the surface by division, but others also reach it by independent migration from the yolk, until, about forty hours after fertilization, the superficial yolk is entirely segmented. About thirty segments are now present. The cells over one-half of the egg (those which have reached the surface first) are often preparing to divide by the time the yolk over the opposite side is completely segmented. This handicapping of certain cells by others still further tends to produce irregularities in the early phases. This irregularity, however, soon disappears, so that individual eggs have their yolk uniformly divided. Nuclear division arises by karyokinesis, various stages of which can be followed with the subsequent cleavage of the cell or segment. Individual eggs were kept under observation for upwards of five hours. Alternating periods of rest and activity follow the first division until the superficial segments are reduced to a regular pavement of very small cells.

Irregularities of segmentation are so numerous that only a few can be mentioned. Quite often one meets with eggs composed of several hundred segments, some very small, others very large, and others of various intermediate sizes. The eggs which were laid by a lobster kept in an aquarium, referred to in another paper, segmented in an irregular fashion very similar to this. Again, eggs otherwise regularly segmented may contain a large superficial mass of unsegmented yolk. Then one meets with eggs with yolk quite unsegmented with the exception of 2–6 small segments on one part of the surface. In one egg more anomalous than usual, there was a very small spherical segment containing a nucleus, while the rest of the egg was entirely undivided, so far as the yolk was concerned. This egg in reality contained about six nuclei.

All or nearly all of these irregular cases, as well as others which will be noticed later, appear to reach a normal condition eventually. The time occupied by the segmentation processes, and other details, are shown by the following table:

TABLE I.

No.	Date.	Hour.	Temp. Surface Water.	Age of Egg.	Stage.	Remarks.
1 (1)	1890 Jl. 30	1.45 p. m.	Fah. 72°	8 hrs. (?)	Yolk unsegmented.	2–4, possibly fewer nuclei.
1 (2)	do	6.00 p. m.	72	12¼ hrs.	do	
1 (3)	do	10.00 p. m.	72	16¼ hrs.	do	
1 (4)	Jl. 31	10.00 a. m.	72	28¼ hrs.	Segmentation of yolk.	Only a few eggs with yolk segmented.
1 (5)	do	2.00 p. m.	72	32¼ hrs.	do	Only a few with unsegmented yolk.
1 (6)	do	6.00 p. m.	72	36¼ hrs.	do	Several stages: some eggs with about 30 segments; some with very small, numerous segments; a few with unsegmented yolk.
1 (7)	Aug. 1	9.30 a. m.	72	51¾ hrs.	do	Majority of eggs with at least 160 segments; some unsegmented; some irregular.
1 (8)	Aug, 2	12.00 m.	72	77¾ brs.	do	Majority of eggs with superficial layer of very small cells (segments); rarely an egg with unsegmented yolk.
1 (9)	Aug. 3	11.00 a. m.	72	100¾ hrs.	Invagination.	Majority of eggs in this stage.
1 (10)	Aug. 4	9,00 a. m.	72	122¾ hrs.	do	
2 (1)	1889 Jl. 11	5.30 p. m.	68		Yolk Segmentation.	Late stage. About equivalent to 1 (7) above. Cell protoplasm not quite at surface.
2 (2)	Jl. 12	9.30 a m.	68	16 brs. +	do	Protoplasm generally at surface, and cells most numerous on one side of egg.
2 (3)	Jl. 13	1.00 p. m.	69	43½ hrs. +	Invagination.	
2 (4)	Jl. 14	5.45 p. m.	69	72¼ hrs. +	do	Depression at surface slight. Keel forming.
2 (5)	Jl. 18	9.50 a. m.	68	160¼ hrs. +	Keel.	Depression larger.
2 (6)	Jl. 19	12.20 p. m.	68	174¾ hrs. +	do	Nauplius not yet outlined.
3 (1)	Jl. 10	11.00 a. m.	68		Keel.	
3 (2)	Jl. 11	12.45 a. m.	68	24¾ hrs. +	Egg Nauplius.	1st antennae and mandibles outlined. 2d antennae not budded.

The lobster numbered one—$1^{(1-10)}$—in Table I was taken directly from the pot in which it was caught, and the eggs are assumed to have been laid eight hours. It is probable that they had not been laid longer than this, and possibly a much shorter time.

The segmentation stages occupy about three days under conditions shown in the table. By the end of the fourth day the invagination stage is reached. This is followed by the keel-stage, which lasts about four days. At the beginning of the tenth day the naupliar appendages begin to bud forth, first the first pair of antennae and mandibles together, and a little later the second pair of antennae.

In number two—$2^{(1-6)}$—of Table I about fifty hours should be added after each plus sign in the column which shows the age of the egg.

Table II shows the progress of development in eggs taken from the same lobster. The latter was caught at the very beginning of the spawning season and was kept confined in a latticed box in the water off the Fish Commission's wharf at Wood's Holl during the fall and winter. Sections of eggs taken December 1st and January 1st do not exhibit marked changes in development, but surface views of the embryos, and the relative size of the black eye-spots (which serve as a good measuring guage) prove that considerable progress is made by the growing embryo during this month. This is also seen in the gradual absorption of the food yolk.

The histology of the early stages of segmentation shows a number of interesting things, one of which has already been mentioned—the fact that the protoplasm does not migrate as a body to one side of the egg, and thence spread over the entire surface. The protoplasm segments first in or near the centre of the egg. Its products pass out towards the periphery, and some of them outstripping the rest, reach a part of the surface first, where they initiate the segmentation of the yolk.

In two eggs examined, each of which contains two nuclei, one nucleus in each case lies nearer the centre and the other nearer the surface. The nuclei are relatively small, and after a few divisions they become very much smaller. Each is surrounded by a rayed body of protoplasm. The rest of the egg consists of yolk spherules and is enclosed by a single membrane, the chorion.

TABLE II.

No.	Date.	Hour.	Temp. Surface Water.	Age of Egg.	Stage.	Remarks.
4 (1)	1890 Jl. 9	3.45 p. m.	Fah. 71°	8 d. 3 hrs. (?)	Keel.	Depression in midst of keel very marked.
4 (2)	Jl. 11	12.45 p. m.	69	10 d.	Egg-nauplius.	2d anteonæ not budded, or just budding.
4 (3)	Jl. 15	10.30 a. m.	69	14 d. 2¼ hrs.	do	2d antennæ hiramous: thoracic-abdominal fold.
4 (4)	Jl. 17	12.00 m.	70	16 d. 3¾ hrs.	do	Late egg-nauplius.
4 (5)	Jl. 22	12.00 m.	70	21 d. 3¾ hrs.	Post-nauplius.	4-5 pairs post-mandibular appendages; tip of abdomen conspicuously forked; optic discs lobular.
4 (6)	Jl. 25	10.30 a. m.	69	24 d. 2¼ hrs.		Optic lobes very large: tip of abdomen overlaps brain: 6-7 pairs post-mandibular appendages: antennæ and telson tipped with rudimentary setae.
4 (7)	Jl. 27	——	70	26 d. 2¼ hrs.		Tip of abdomen reaches roots of optic lobes.
4 (8)	Jl. 29	5.00 p. m.	71	28 d. 8¾ hrs.		Eye pigment present for about 24 hrs.
4 (9)	Aug. 3	10.30 a. m.	72	33 d. 2¼ hrs.		Eye-spots crescentic or semi-circular: telson extends over optic lobes.
4 (10)	Aug. 12	12.30 p. m.	72	42 d. 16¼ hrs.		Eye-spots oval: telson considerably in front of optic lobes.
4 (11)	Sep. 1	——	—	61 d.		
4 (12)	Oct. 1	——	—	91 d.		
4 (13)	Nov. 1	——	—	122 d.		
4 (14)	Dec. 1	——	—	152 d.		
4 (15)	Jan. 1	——	—	183 d.		Eye-spots nearly circular: red pigment developed on abdomen.
4 (16)	Feb. 1	——	—	214 d.		
4 (17)	Mar. 1	——	—	242 d.		

In an egg containing nineteen nuclei, with yolk undivided, eight of these nuclei are in various stages of karyokinesis. Some of the cells are nearer others farther from the surface, the majority being about midway between the centre and periphery, in different parts of the egg.

In an egg with the segmentation of the superficial yolk completed, just thirty-four cells or yolk pyramids are present. The constrictions of the yolk are not simply superficial, but cleavage planes often reach down half way to the centre of the egg. The nucleus with its rayed protoplasm lies toward the centre of the convex face of each segment, but it is still separated from the surface of the egg by a considerable layer of yolk. The entire protoplasm is thus distributed among the yolk segments, none of it remaining in the undivided yolk below. Nuclear division is now radial, but at a later period, after a large number of small segments have been formed, some of the nuclei begin to divide tangentially, that is delaminate, and their products pass into the yolk below the superficial cells. These cells, which migrate from the yolk pyramids, were described in a former paper (*University Circulars*, No. 80), but the actual migration could not be so clearly demonstrated in the material then at command.

In an egg in which twenty-nine nuclei are present the superficial yolk is also involved in segmentation. In an egg with twenty nuclei, five are in karyokinesis near the surface. The latter initiate later the segmentation of the yolk.

Invagination Stage.

When the latest stages of segmentation—$1^{(8)}$ of table—are reached, the surface of the egg is covered with a layer of very small cells. In surface views dividing nuclei are seen, and nuclear nests or clusters which appear in reflected light, as small white spots. The latter are situated either at the surface or just below it. A small patch of cells is soon formed at a certain point on the surface. These cells are invaginated, and a small circular pit soon appears in their midst. On one side of the pit, its anterior side, and over a considerable surface of the egg, the cells multiply rapidly, and thus mark off the embryonic area. Behind the pit, cell division is relatively slow. The pit is at first very shallow, and many of its cells begin to proliferate rapidly on all sides.

The Keel.

The preceding stage inaugurates the formation of a structure which will be called the "keel." I now prefer to regard the invagination as an invagination simply, and not necessarily as the remnant of a gastrula stage. It is fugitive and has no relation to either mouth or anus of the adult. It appears to be simply the initiatory process by which a large mass of cells, the keel, is built up. The significance of this invagination will be discussed in the completed report.

The keel and some of the following stages have been briefly described in another paper, to which reference has already been made (*University Circulars*, No. 80). The keel stage lasts 3–4 days, and terminates in the egg-nauplius. The depression, at first very slight, becomes deeper and broader, and is easily seen with the naked eye. It involves a considerable number of the surrounding cells; and all the cells, both those which at any one time form its walls, and those which pass into the general yolk immediately below, proliferate and gradually build up a large mass of cells—the keel. Eventually the depression entirely disappears, and in its place we have a plug or core of cells extending downward into the yolk, and backward in a conspicuous train. There is much variation both in the time of disappearance of the pit, and in the shape and size of the keel. On the anterior portion of the keel and on the anterior half of its sides, the superficial cells are multiplying rapidly. This proliferation extends forward and laterally, and thus includes a considerable area, which forms the embryonic area just noticed.

By the time the naupliar appendages are outlined the keel has undergone remarkable changes, and is no longer visible as a prominent object at the surface. Some of its cells pass forward under the embryonic area; some take part in the thoracic-abdominal process, while a very large number pass into various parts of the egg in a way already described in an earlier paper. The optic discs, the naupliar appendages and thoracic abdominal process, appear at first as more or less distinct patches of cells in the embryonic area. The first antennae and mandibles bud out simultaneously. When these appendages are outlined the invagination of the fore-gut is present as a small circular pit on a line with the first antennae. The labrum or lip then grows down over this depression. Shortly after the lip is formed the second pair of antennae are budded.

I wish now to speak of some curious variations or irregularities which occur in relation to the keel and the egg-nauplius which follows. There is frequently formed in connection with the keel an oval, circular or irregularly shaped disc of cells, of from one to two-thirds the diameter of the egg. The edges of the disc grow down into the yolk, so that they are sharply defined all around. Either wholly or partly within this area, or upon its edges, the embryo is formed. Sections through the disc show that it consists, for the most part, of a single layer of very large, columnar or cubical cells, gorged with yolk. The edges bend down and grow into the yolk, entirely independent of the general epithelium covering the remaining surface of the egg. Furthermore, the edges of each side in front and behind unite to form a cul-de-sac at each end of the disc, so that the whole structure represents a flattened bag, partly buried in the yolk, and in communication with the latter by an opening below. The edges of the plate are sometimes curled over in the yolk like the lower limb of the letter χ. Sometimes the whole disc sinks into the yolk, so that the nauplius embryo is nearly covered by yolk material. This recalls the condition of the insect embryo after the amnion and serosa are formed. So far as I have observed, there is a very slight growth, if any, of surface epithelium over the disc. Cells of the disc proliferate and send their products into the yolk below.

Another irregular form which is sometimes met with in connection with the keel, is where there appears from the surface to be a deep transverse invagination. This is sometimes long and narrow, or crescent-shaped. This really represents the invagination or engulfing of a contracted cell-area of the same nature as the disc already described. A rather more anomalous variation is where a single cavity or several communicating cavities are formed in the yolk, each with definite cell-wall. (For fuller account see *University Circulars*, No. 80).

Throughout the whole extent of this embryo from the optic discs to the thoracic-abdominal process, there is a meteoric cloud of "spores" or fragmented, degenerating nuclei, which pass into the yolk, and are later absorbed. Nests of cells also occur in the yolk, some of which are degenerating, in addition to the long trains of peculiar cells which are coextensive with the yolk and are derived from the keel (see *University Circulars*, No. 80). The peculiar embryos just described, all I believe, attain eventually to the norma or usual condition.

Degenerating nuclei occur in the fully formed egg-nauplius in various parts, but are most noticeable perhaps in the region of the stomadaeum and optic discs. I believe it will be found that the fragmentation and dissolution of cells is a common phenomenon among the Crustacea and other Arthropods. I have already observed it in several Decapods, and it seems quite possible that the "secondary mesoderm cells," which have been described in the Crayfish, may be explained in part at least as cases of cell-degeneration. In the peculiar "dorsal organ" of the lobster which was described in the earlier paper, many of the cells proliferate and then break up into spore-like, degenerating products, precisely as in Alpheus Sauleyi. The history of the degenerating cells is very similar in the two forms. The history of the later stages will be given in another abstract.

CLEVELAND, OHIO, January 10th, 1891.

On the Early Stages of Echinoderms. By W. K. BROOKS.

[Abstract of a paper read before the National Academy of Sciences, November 13th, 1889; Report of the National Academy of Sciences, 1889, p. 12.]

Several observers have recorded the occurrence of a right water pore and pore canal, as well as those which normally occur on the left side, but as these structures have usually been observed in captive larvae, which have suffered more or less from the injurious effects of captivity, they have been regarded as monstrosities, due to unnatural conditions.

In the summer of 1889 I collected with a tow net, in the open waters of Wood's Holl, great numbers of normal, vigorous starfish larvae, and upon studying their structure by serial sections, I found that the water system is at first bilaterally symmetrical in every particular, although the right water pore and pore canal degenerate and disappear very early in the life of the larva, so that the older larvae exhibit no traces of those structures.

Soon after the ciliated bands make their appearance an ingrowth of the ectoderm, on each side of the stomach, at a considerable distance from the middle line of the body, gives rise to the water pore and to the ectodermal portion of the pore canal, meeting and uniting with a tubular outgrowth from the enterocele. When the starfish larva reaches a stage of development which resembles the diagram which Balfour has given in Fig. 254 B, of his Comparative Embryology, each enterocele has a fully developed canal to the exterior, but very soon the right one degenerates and disappears while the left migrates towards the middle line of the body.

The phenomenon in question has a direct bearing upon the significance of the ciliated, bilateral, swimming larva of echinoderms, and it furnishes a strong argument in favor of the view that the larva is ancestral; for we should not, if the bilateral symmetry is ancestral, expect it to involve structures which do not stand in relation to the bilateral environment of the swimming larva. A bilateral structure which loses its symmetry almost at the beginning of the locomotor life, cannot be an adaptation to locomotion.

The resemblance between the paired pore canals of the starfish larva and such structures as the spiracles of Appendicularia and tunicate larvae is also worthy of note, as in each case we have paired ectodermal involutions meeting and fusing with diverticula from the digestive tract.

Contributions to the Embryology of Asterias Vulgaris. By GEORGE W. FIELD.

In view of the morphological importance of the question as to the probability of the larval form, Bipinnaria, of the Starfish being ancestral, I began in November, 1890, work on certain problems in the development. Gradually new questions came up for solution, and the work involving an extensive examination of the voluminous and scattered literature, it was deemed advisable to go over the entire life history. This work is now well in hand. As the work on the stages previous to the metamorphosis is now practically completed, it seemed best to call attention to certain points, in advance of the more complete consideration.

During the summer of 1889, at Woods Holl, Mass., Dr. W. K. Brooks found in the surface collections, Bipinnarias with a right and a left water pore. In older Bipinnarias there was only the left water pore.

Soon after Dr. Brooks very kindly placed at my disposal all his valuable material and preparations. This was supplemented by study of the live material at Woods Holl, last summer, where through the courtesy of Col. Marshall MacDonald I enjoyed the privileges of the U. S. Fish Commission Laboratory. To Dr. Brooks I am indebted for many valuable suggestions; my thanks are also due Dr. H. V. Wilson for numerous favors. The material for the early stages was obtained from eggs discharged and fertilized normally in aquaria. The developing larvae were kept in glass jars, in which were placed some Ulvaceae, with hopes that the zoospores set free might furnish to some extent food for the young larvae.

Oögenesis.

The wall of the ovary is formed by a layer of muscular fibres in bundles, and connective tissue. The inner surface of this layer is covered by germinal epithelium. The cells of this germinal epithelium increase in size and push towards the lumen of the ovarian sack, and at length appear as projections of, and finally separate from, the germinal epithelium. At first the increase in size is very much greater in the nucleus than in the cytoplasm; but just before the cell becomes free from the germinal epithelium the granular cytoplasm increases very rapidly. The eggs within the cavity and ovary are of irregular shape from mutual pressure. Among the eggs near the periphery are many branching cells with extremely long and delicate processes. After the eggs have been discharged these cells, with their processes, remain and fill the now somewhat contracted lumen with a fine network.

Spermatogenesis.

The walls of the gland have the same character and constituent parts as the ovary, except that the muscular layer is less developed. Numerous supporting trabeculae of connective tissue run out from the wall towards the centre of the lumen. The cells of the germinal epithelium increase in size, become free, and are pushed towards the centre. When near the centre they rapidly divide into two equal cells; these in turn divide, so that the mother cell by division forms *four* spermatozoa.

Mesenchyme.

During cleavage, as the 16 cell stage there is a distinct, though slight difference in the size of the cells. This difference is apparent during the remainder of the cleavage process; but attempts to trace back the mesenchyme to a definite cell or cells have been unsatisfactory. My conclusions as to the origin of the mesenchyme are: (1) That the mesenchyme formation precedes, and is continued during the process of invagination. (2) That cells in the entodermic region of the blastula divide transversely; the part next to the segmentation cavity becomes amoeboid, and wanders freely in the jelly-like substance, filling the segmentation cavity. (3) That any entodermal cell may by division, and also probably without division, become a free, wandering mesenchyme cell; therefore, the condition found in Asterias tends to confirm the view of Metschnikoff and Korschelt as to the absence of two "Urmesenchymzellen" in the echinoderms; and differs from Metschnikoff's observation on *Astropecten* in the appearance of mesenchyme cells before the beginning of invagination.

The amoeboid mesenchyme cells form a supporting network between the external walls and the digestive tract. Many of the cells apply themselves to the walls of the body, and of the digestive tract. On the body wall they become flattened and form a discontinuous lining: on the walls of the oesophagus, by the formation of long, delicate, anastomosing processes, they form a very evident circular, and a less distinct longitudinal musculature. The circular fibres are differentiated very early in the entodermic portion of the oesophagus, even before its junction with the stomodoeum.

Ciliated Bands.

Concerning the ciliated bands of the Bipinnaria Semon (Die Entwickelung der Synapta digetata, *Jen. Zeitschrift*, XXII, page 185) says: "Bekanntlich untersheiden sich die Asteridenlarven von der Larven der anderen Klassen dadurch, dass sie *zwei*, nicht *eine* Wimperschnur besitzen. Diese recht befremdliche Thatsache findet eine einfache Erklärung dadurch, dass die zweite Wimperschnur der Asteriden—dieselbe umgiebt ein Gebeit, welche dem vorderen Ventralfeld der Auricularia entspricht—von der bisher übersehenen adoralen Wimperschnur ihren Ausgang nimmt und dauernd mit ihr im Zusammenhang bleibt."

In the young bipinnaria soon after the union of the stomodoeum and mid-gut, the cilia which previously covered the entire surface of the body, begin to disappear on the ventral side. They persist over two areas, a preoral and a postoral, as transverse lines. From the flattening of the other cells of the surface these areas are left as ridges, and these are the first sign of the ciliated band. There is *no trace of a connection between this, which is to become the long, sinuous, ciliated band,* and *the band (called by Semon the adoral) surrounding the mouth.* Gradually the disappearance of the cilia extends dorsally and anteriorly; and at the same time the band extends slowly from each end of the preoral and postoral transverse portion; the latter is much longer, and meets the preoral part at the anterior pole, and uniting forms a *single* continuous, bilaterally symmetrical, ciliated band. The cilia disappear last at the apex of the preoral lobe, and before the union of the two parts of the band, the cilia are still to be seen at this point. I wish to show that in Asterias, at least, there is no trace of a primary connection between the two ciliated bands, but that the connection mentioned by Semon is secondary and occurs only in the farther development of the bipinnaria.[1]

Apical Plate (Scheitel Platte).

An optical section through the apex of the preoral lobe of the living animal shows an ectodermal thickening. Longitudinal sections of the preserved specimens show, in the early bipinnaria stage, an ectodermal thickening, caused by the more columnar character of the cells over a small region between the links of the longitudinal ciliated band. This thickening, which corresponds exactly in position with the apical plate of Tornaria, is without the pigment spots of the latter. I have not yet made macerations of this region; but in sections I cannot be certain that there are any nerve fibres or cells here. This structure is possibly the first trace of an apical plate, comparable to that found in a higher phase of development in Tornaria and Trochophore larvae.

Enterocoels and *Dorsal Pore.*

The enterocoels, as is well known, arise universally among the echinoderms, as paired lateral and slightly dorsal diverticula of the archenteron. The usual description is "that the left enterocoel early acquires an opening to the exterior." At about the end of the third, or at the beginning of the fourth day after fertilization of the egg, the enterocoels lying to the right and left of, and dorsal to the oesophagus, have an ovoid form, with walls formed of flattened mesenchyme-like cells. To form the water pore and pore canal, a part of the dorsal wall of the enterocoel pushes up a hollow cylindrical protuberance, which meets a solid plug of the proliferating dorsal ectoderm. This ventrally directed plug acquires a lumen, and thus puts the cavity of the enterocoel in communication with the exterior. The pore canal is therefore formed from entodermal and ectodermal elements. This observation, made on the living animal and confirmed by sections, differs from Bury's account: "Examination of the living animal, under a high power, shows that the pore is formed by a single elongated cell, perforated throughout its length, and lined by cilia." (*Quar. Jour. Micr. Soc.*, XXIX, p. 411). Bury's observation, however, was not made on an Asterid.

In the manner which I have described above, are formed a *right* and a *left* dorsal pore. But within a very short time (from 6 to 12 hours) the right pore becomes closed by a pushing together of the ectoderm cells around the opening; but the canal leading to the right enterocoel persists for some time, gradually becoming obliterated. Specimens of bipinnaria with two water pores have been described by different investigators, but have been characterized as pathological. I believe the stage with two bilaterally symmetrical water pores is a definite stage in the ontogeny of Asterias, and that it has a phylogenetic significance.

---

[1] This observation was made on the living specimens in July, 1890. A few days ago I found that Semon himself had investigated this point very completely; and by work on *Asterias rubens*, in April, 1890, had found that the condition of the ciliated bands of the Bipinnaria was not as he had previously supposed. The same conclusions were therefore arrived at independently in different Asterids.

The results of his work are found in the last number of the *Jenaische Zeitschrift* (XXV Bd., Heft. I.).

Later History of the Enterocoels.

After the degeneration of the right water pore, both enterocoels elongate anteriorly, in position nearly parallel and somewhat dorsal to the oesophagus, until they meet and unite in the preoral lobe. The growing end of each enterocoel is solid for a considerable distance, and is formed of indifferent mesenchyme-like cells. Behind this growing point the cells are flattened and their processes are early differentiated into delicate muscle fibres. During this anterior growth there has been an extension posteriorly, and also dorsally and ventrally. Later at a point just posterior to the pore canal a constriction is noticed, which soon completely divides the left enterocoel into an anterior and a posterior enterocoel. Just anterior to this constriction, and therefore in the posterior part of the left anterior enterocoel, and at a time previous to the complete separation of the two enterocoels, appear the five thickened outpushings of the wall, the future Hydrocoel, destined to give rise to the circumoral water-vascular ring and the five radial vessels. This does not, I believe, separate from the anterior enterocoel even during metamorphosis, and the anterior part of the original enterocoel disappears only with the absorption of the larval organism by the maturing starfish. The presence of a right and a left water pore has been shown for some species of Balanoglossus, and I believe that the condition described above will be found in other echinoderm larvae. During the present year I intend to extend work on this point to as many species as possible.

The view that the bilateral larval form of the echinoderms is ancestral, and not secondarily acquired, is gaining ground. In addition to the evidence already brought forward by various investigators, I wish to call attention to the apparently ancestral, and important phylogenetic and ontogenetic character, of the presence in a Bipinnaria of a stage with bilaterally symmetrical water pores, homologous in their mode of origin, and probably in function, with nephridia; and also the presence of a structure comparable to a simplified apical plate (Scheitel platte).

Johns Hopkins University, Feb. 16, 1891.

Introductory Note to Professor W. K. Brooks's Volume on The Oyster. By D. C. Gilman. See page 104.

(*Reprinted from the Volume.*)

This book (for which I have been asked to write an introductory note) is written for the information of all who care for oysters,—no matter whether their point of view be that of providers or consumers,—of the oysterman, the money maker, the housekeeper, the legislator, the editor, or the student of natural history. So well is the book written that many parts of it are as fascinating as a story.

The facts that have led to its preparation are these. After many years of plenty, Maryland is in danger of an oyster famine. The supplies which nature bestows most bountifully have been so treated that scarcity now takes the place of abundance, anxiety and alarm have followed security. Authentic figures showing the decline and fall of the oyster empire of the Chesapeake, startle all who consider them. It is not only the dredgers, the dealers, the shuckers, the packers, the coopers, the tinners, and the carriers, that are to suffer if this state of affairs continues, everybody in Maryland will likewise suffer more or less. An important article of food, that should be as plentiful as it is excellent, will grow more scarce, and a branch of industry will be cut off, which employs a large amount of labor and of capital and so contributes to the welfare of the state, the region, and the country. The interior as well as the sea-board, the farmer as well as the oysterman, will be injured unless some remedy is found.

The author of this volume is well known in all scientific circles, as an accurate, clear-sighted and trustworthy observer. His papers are received and quoted by the best authorities in every place where the study of natural history is carried on. Not only can he see with his trained eye and powerful glasses, more than most people, but he can state distinctly and without any deviation from the exact truth, what he sees, and what he thinks of what he sees. His life has been devoted to the careful observation of the forms and changes of form in living beings.

To the study of the oyster he has devoted a large part of his time for more than ten years past, having been encouraged to do so by the Johns Hopkins University, in which he is an honored professor, and by the legislature of the State of Maryland, which he served as an oyster commissioner in 1883–4. He can hold his own not only among naturalists, but also among practical men. He has dredged in every part of the bay. To use his own words, he has tonged oysters in five different States; in the warm waters of the South, he has spent months under the broiling tropical sun, wading over the sharp shells which cut the feet like knives, studying the oysters "at home." He has planted oysters; he has reared them by collecting the floating spat; and he has hatched from artificially fertilized eggs more oysters than there are inhabitants of the United States. More than this, he has diligently studied the experience of other States and countries and has gathered up the knowledge of the world in respect to the life of the oyster, its enemies and its needs, its dangers and its protections. The people of Maryland may rejoice that in just this crisis, the State has the service of such a citizen, ready without any reservations and without any expectations of reward, to give his hard-earned knowledge to the public.

But the author has another claim to be heard. He is governed by common sense. The difficulty that he sees is summed up in a single sentence that he prints in capital letters, THE DEMAND FOR CHESAPEAKE OYSTERS HAS OUTGROWN THE NATURAL SUPPLY. The remedy he proposes is to increase the supply by artificial means. To show what is possible for the propagation and protection of young oysters he describes in the most interesting manner, in terms scientific enough to be accurate, not so scientific as to be hard of understanding, the life history of the bivalve. The oyster's exposure to infantile dangers, its preferred home, its dietary habits, its susceptibility of culture, its wonderful fecundity, are vividly portrayed. Indeed, this modest volume is at once a memoir in natural history, and a chapter of political economy.

CONTENTS.

PAGE.

On the Structure and Development of the Gonophores of a Certain Siphonophore belonging to the Order Auronectae (Haeckel). By **W. K. Brooks** and **E. G. Conklin.** With one plate, - - 87

Preliminary Note on the Embryology of Crepidula fornicata and of Urosalpinx cinerea. By **E. G. Conklin,** - - - - - - 89

Notes on the Physiology of Caravella Maxima, Haeckel (Physalia Caravella, Eschscholtz). By **Robert Payne Bigelow,** - - 90

Preliminary Notes on Some New Species of Squilla. By **R. P. Bigelow,** - - - - - - - - - - - - - 93

The Anatomy and Transformation of Tornaria. A Preliminary Note. By **T. H. Morgan,** - - - - - - - - - - 94

PAGE.

The Distribution of Magelona. By **E. A. Andrews,** - - - - 96

Time of Flowering of Hepatica triloba. By **Basil Sollers,** - - 96

Notes on the Habits and Larval Stages of the American Lobster. By **F. H. Herrick,** - - - - - - - - - - - 97

The Reproductive Organs and Early Stages of Development of the American Lobster. By **F. H. Herrick,** - - - - - 98

On the Early Stages of Echinoderms. By **W. K. Brooks,** - - 101

Contributions to the Embryology of Asterias Vulgaris. By **George W. Field,** - - - - - - - - - - - - 101

Introductory Note to Professor Brooks's Volume on The Oyster. By **D. C. Gilman,** - - - - - - - - - - - 103

THE JOHNS HOPKINS PRESS.

THE OYSTER.

A POPULAR SUMMARY OF A SCIENTIFIC STUDY.

BY WILLIAM K. BROOKS, PH. D.

Professor Brooks's reports on the "Embryology of the Oyster" and on "The Oyster Industry of Maryland," which were published by the Johns Hopkins University in 1879 and 1884, are now out of print.

In accordance with many requests he has made a complete revision of his former works, and has added much new matter.

Professor Brooks served as one of the Oyster Commission of the State of Maryland in the years 1883–84, and has received from the Société d'Acclimatation, of Paris, in 1880, its medal for his researches on the development of the oyster.

The subjects specially discussed are:—

The Possibilities of Oyster Culture.
The Anatomy of the Oyster.
The Development of the Oyster.
The Artificial Cultivation of Oysters.
The Cause of the Decline of the Oyster Industry and the Protection of the Natural Beds.

This volume is just ready (May, 1891). It contains 240 pages, 12o, and 14 lithographic plates, and is bound in cloth. The price is one dollar net.

SELECTED MORPHOLOGICAL MONOGRAPHS,

VOLUME I.

BY MEMBERS OF THE JOHNS HOPKINS UNIVERSITY.

EDITED BY W. K. BROOKS, PH. D.

370 *pages and* 50 *plates*, 4o. *Cloth. Price*, $7.50. 1887.

CONTENTS.

I. Lucifer: a Study in Morphology, with 11 plates. By W. K. BROOKS.

(Reprinted from the Philosophical Transactions of the Royal Society of London, 1882, Part I.)

II. The Development of Renilla, with 16 plates. By E. B. WILSON.

(Reprinted from the Philosophical Transactions of the Royal Society of London, 1883, Part III.)

III. The Life-History of the Hydro-Medusae: a Discussion of the Origin of the Medusae, and of the Significance of Metagenesis, with 8 plates. By W. K. BROOKS.

(Reprinted from the Memoirs of the Boston Society of Natural History, 1886; Volume III, Number XII.)

IV. Report on the Stomatopoda, with 16 plates. By W. K. BROOKS.

(Reprinted from the Report on the Scientific Results of the Voyage of H. M. S. Challenger, during the years 1873–76: Zoölogy: Volume XVI, Part XLV, 1886.)

A MEMOIR ON THE GENUS SALPA.

BY WILLIAM K. BROOKS, PH. D.

The Johns Hopkins Press announces for publication a Memoir on the Genus Salpa by Professor W. K. Brooks. It will contain about two hundred pages, quarto, with fifty colored plates. The Memoir is based for the most part on material collected by the United States Fish Commission.

The following subjects are treated:

The General Natural History of Salpa and its Allies.
Descriptions of North American Species of Salpa and Doliolum.
The Embryology of Salpa.
The Development of the Salpa Chain, and the History of the Process of Budding in Salpa and Doliolum.
The Phylogeny of Salpa, the Evolution of the Proliferous Stolon, and the Significance of the Polymorphism of Salpa.
The Geographical Distribution of the Species of Salpa considered in their relation to the circulation of the surface water of the ocean.

Advance orders will now be received. The edition will be limited. The price is fixed at $5.00 net.

STUDIES FROM THE BIOLOGICAL LABORATORY.

H. NEWELL MARTIN, Ph. D., M. D., Professor of Biology, EDITOR; *W. K. BROOKS, Ph. D., Professor of Animal Morphology,* ASSOCIATE EDITOR.

The publication of the Studies from the Biological Laboratory was commenced in 1879, in order to secure publication in the United States of the results of researches carried out in the Biological Laboratory of the University and in its Chesapeake Zoölogical Laboratory. Most of the original biological work of members of the University since 1879 has been published in these "Studies."

Four volumes have already been issued, and Vol. V. is in progress. Each volume contains about 500 large octavo pages, and numerous plates. The subscription per volume is $5.00: separate numbers may be purchased at a price varying with their size and the number of plates they contain. The first three volumes are now out of print.

The latest papers issued in this series have been:

VOL. IV., NO. 7. PRICE $1.00.

Notes on the Anatomy of Sipunculus Gouldii Pourtales. By E. A. ANDREWS. 52 pages, 8o, and 4 plates.

The Relationships of Arthropods. By H. T. FERNALD. 82 pages, 8o, and 3 plates.

VOL. V., NO. 1. PRICE $1.50.

A Contribution to the Embryology and Phylogeny of the Pycnogonids. By T. H. MORGAN. 76 pages, 8o, and 8 plates.

Orders and remittances for any of the above volumes should be addressed to THE JOHNS HOPKINS PRESS, BALTIMORE.

The Johns Hopkins University Circulars are printed by Messrs. JOHN MURPHY & CO., No. 44 West Baltimore Street, Baltimore, from whom single copies may be obtained; they may also be procured from Messrs. CUSHING & CO., No. 34 West Baltimore Street, Baltimore. Subscriptions $1.00 a year, may be addressed to THE JOHNS HOPKINS PRESS, BALTIMORE; *single copies will be sent by mail for ten cents each.*